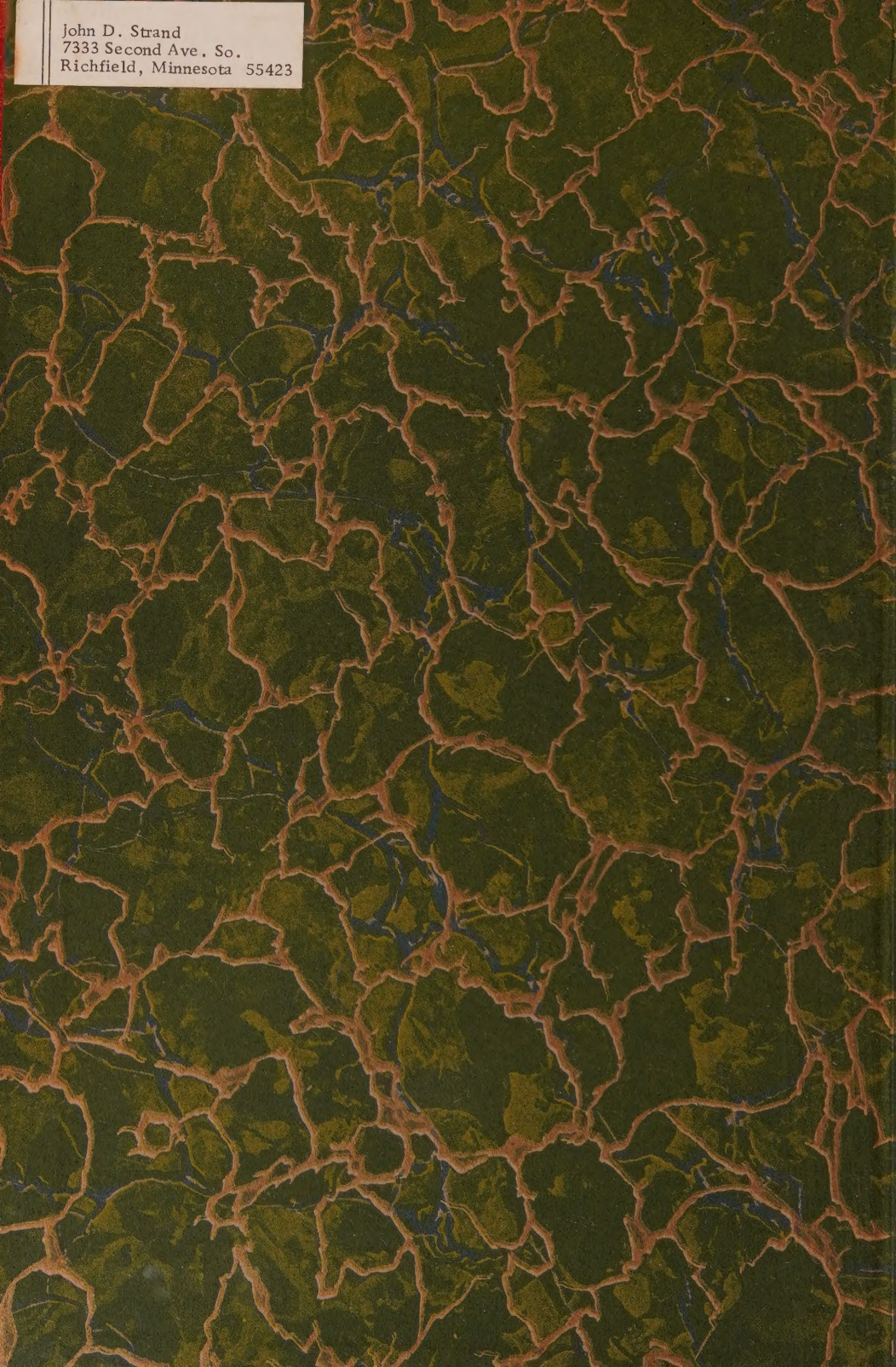
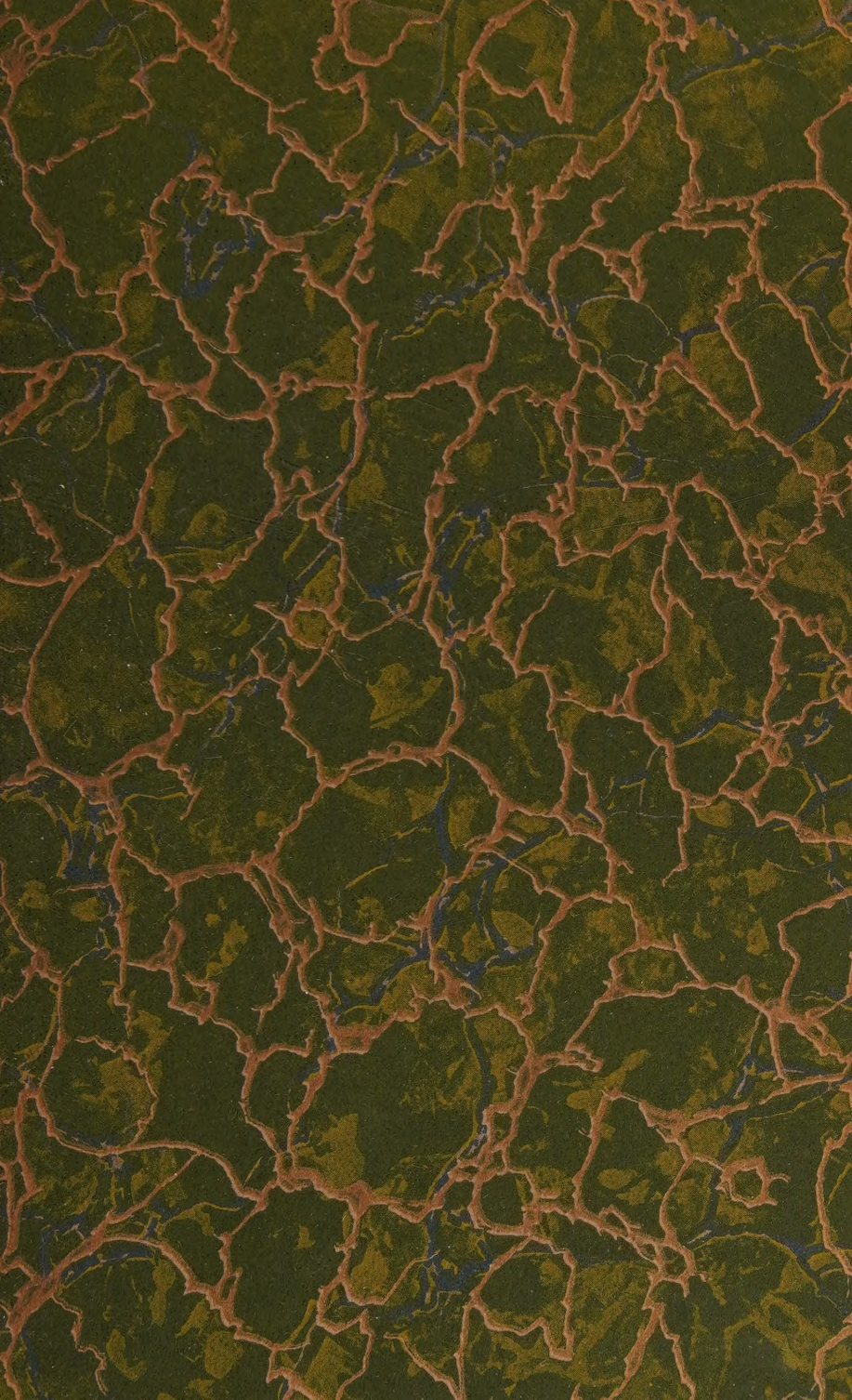


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Brickwork, Terra Cotta, and Concrete

247 ILLUSTRATIONS, 8 IN COLORS

Prepared Under Supervision of

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COMMON BRICKWORK
ARCHITECTURAL TERRA COTTA
FACE AND ORNAMENTAL BRICKWORK
CONCRETE CONSTRUCTION

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PREFACE

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The great majority of our students wish to prepare themselves for advancement in their vocations or to qualify for more congenial occupations. Usually they are employed and able to devote only a few hours a day to study. Therefore every effort must be made to give them practical and accurate information in clear and concise form and to make this information include all of the essentials but none of the non-essentials. To make the text clear, illustrations are used freely. These illustrations are especially made by our own Illustrating Department in order to adapt them fully to the requirements of the text.

In the table of contents that immediately follows are given the titles of the Sections included in this volume, and under each title are listed the main topics discussed.

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COMMON BRICKWORK

BRICK

1. Definition and Description.—Bricks may be defined as solid building units made of burned clay. They are comparatively small in size, therefore easily handled, and being already burned are extensively used in buildings that are intended to be fire-resistive and in other forms of construction that are permanent in character. When referred to in the mass, or as a building material, they are called *brick*.

Brick can be made cheaply and, when hard burned and laid in good mortar, is one of the most durable building materials in use. Common brick can be used to form solid, or even hollow, walls when desired, or can be used to back up a wall that is faced with a most costly material, such as face brick, terra cotta or stone. While common bricks are manufactured mainly with a view to service, they may be used for facing walls. In many localities the clays or shales used in making common brick produce, when burned, a variety of colors and textures resulting in the most pleasing effects as laid in the wall. These effects may be obtained by using the bricks as they come from the kiln without selecting, or by selecting and grading the bricks. The possibilities of artistic treatment of wall surfaces are not even limited by the range of color or texture. With the use of any good hard brick a variation in color effect and texture of wall surface may be obtained by varying the character of the bond and the size and color of the mortar joint. This use of certain kinds of common brick is also discussed and illustrated in the Section on *Face and Ornamental Brickwork*.

MANUFACTURE OF BRICK

2. Ingredients.—The principal material used in making brick is clay, where naturally suitable as it comes from the clay bank, or a combination of clay and sand, called silicate of alumina. Suitable basic materials of this nature are found throughout almost every state in this country. Brickyards abound in nearly every locality and in the making of brick and other clay products a practically inexhaustible material is drawn upon. This material, as found in nature, generally contains small quantities of other chemical substances such as iron, magnesia, lime, potash, etc. Each of these substances has a particular effect upon the color, hardness, and durability of the brick, and by the judicious use of these substances, either alone or in combination, certain characteristics in the finished brick can be obtained. Such combinations are often made by mixing together two or more clays containing different chemical substances.

HAND-MADE BRICKS

3. In the process of making clay bricks by hand, the clay is mixed with water and worked to a plastic state in a *pug mill*, and then the soft plastic clay is pressed into molds by hand. The molds are sometimes dipped into water, just before being filled with the clay, to prevent the mud from sticking to them when the mold is removed. Bricks molded in these wet forms are known as *slop bricks* and also as *water-struck bricks*. Sand is sometimes sprinkled into the molds to prevent the clay sticking, or to produce a sand-finished texture on the faces as laid, and the bricks from sanded molds are called *sanded bricks*. After the bricks are shaped in the mold, they are removed and laid in the sun, or in a drying house, for 3 or 4 days, after which they are stacked in kilns and burned.

The hand method of making bricks and the sun method of drying, being very slow and laborious, have been almost entirely displaced by more economical and expeditious ones in which the work is done by machinery.

MACHINE-MADE BRICKS

4. Nearly all bricks are now made by machinery. Where they are made on a large scale, steam shovels frequently are used for excavating the clay, and conveyors carry the raw clay to the mill and also convey the molded bricks to the drying sheds and the kilns.

Machine-made bricks are usually formed by one of three methods known as the soft-mud, the stiff-mud, and the dry-clay process.

5. Soft-Mud Process.—In the **soft-mud process**, the clay is soaked in water until soft. It is then thoroughly mixed by machinery, and pressed into molds by a plunger. The bricks are then dried and burned.

6. Stiff-Mud Process.—In the **stiff-mud process**, the clay is first thoroughly ground, and just enough water is added to make a stiff mud. After this mud is mixed in a pug mill, it is placed in a machine having a die the exact size of the brick required. The opening in this die is made the size of either the end or the side of a brick. The machine forces a continuous bar of clay through this die, and as it emerges it is automatically cut into bricks, which are then taken to the drying yard. The bricks that are cut on the ends are called *end cut*. Those cut on the sides are known as *side cut*. The soft bricks are placed in rows in a yard covered by a rough shed, with open sides, where they are sun or air dried for a considerable length of time or are run on special trucks into drying houses and are dried in from 4 to 8 days by steam or waste heat from the kilns. When properly dried they are placed in the kiln and burned.

7. Dry-Clay Process.—The process often employed in the best work is the **dry-clay process**. In this method of manufacturing brick, the clay is used just as it comes from the bank, and is apparently perfectly dry. It contains, however, about from 7 to 10 per cent. of moisture. The clay is filled loosely into molds of the same width and length as a brick, but deeper than the required thickness of the brick. A plunger

that exactly fits the mold is then forced in under heavy pressure and compresses the clay to the size of the brick desired. The bricks are then removed to the kiln and fired.

Molded bricks are made in the same way, the difference being that the mold is made to give the shape of the brick required.

Whenever the term *pressed brick* is used, it should mean brick made by the dry process. There are many so-called *dressed* or *face bricks*, however, that are made by recompressing soft-mud bricks.

DRYING AND BURNING OF BRICK

8. Bricks must be dried before being burned. Soft-mud bricks naturally require a longer time to dry than stiff-mud bricks. Having been properly dried, they are placed in kilns and burned. The types of kilns used are the up-draft, the down-draft, and the continuous kilns. The details of these kilns and their operation will not be described here. The important thing is that the bricks shall be well burned and satisfactory in shape and color. It might be said, however, that bricks burned in the modern forms of kilns are more uniform in color, shape, and hardness than those made in the old-fashioned kiln.

CLASSIFICATION OF BRICK

9. **Common Brick.**—The term *common brick* includes all brick made for structural purposes and produced without artificial scoring or marking of the exposed surface to give especial texture.

The distinguishing line between common and face brick in modern practice seems to be the special mixing of ingredients and the artificial coloring and scoring or rough texture, or the repressing process of the smooth brick, and the fact that face brick are graded, handled, and packed with great care.

Many face-brick plants and nearly all paving plants produce a proportion of common brick. Face brick *culls* are sold as *commons*.

The terms applied to grades of common brick vary in different parts of the country. In some places the bricks, although not alike, are sold without selection or grading. In other places the kiln is graded as *front* brick and *back* brick, the front being hardest burned. In others there are *hard* and *kiln run* brick.

In the overburned brick called *clinkers*, the clay fuses and causes irregular shapes and sizes. These bricks are usually extremely hard and very durable. Clinker bricks are in favor with many architects for ornamental purposes and should be laid with proper bond, size and kind of joint and color of the mortar.

Common bricks burned in the old-style up-draft kilns are classified according to their position in the kiln, which affects the amount of heat to which they are subjected. In some localities three grades of brick are produced in these kilns, namely, *arch* or *clinker* brick; *red*, or *well-burned*, brick; and *soft*, or *salmon*, brick. In other localities four grades are produced, namely: *rough-hard* (corresponding to arch brick), *straight-hard*, *stretcher*, and *salmon*.

Arch, or clinker, brick is the name applied to the bricks that have been nearest the fire and are consequently overburned.

Red, well-burned, or straight-hard, brick constitutes the hardest and the largest part of the product of the kiln; *stretcher* brick being a selection of the most uniform of these.

Salmon brick is the name applied to those that have been farthest from the fire and are consequently underburned and soft. In many localities these are used for interior, or unexposed walls, party walls and others not carrying heavy loads.

In certain localities the clay is of such a composition that the best brick from the kiln is of a salmon color and such brick should not be confused with the salmon brick just described.

The American Society for Testing Materials has adopted names for common brick as follows: *vitrified brick*, *hard brick*, *medium brick*, and *soft brick*. These grades conform in general to the classification just mentioned.

10. Face Brick.—Face bricks are made of specially selected materials so that the brick shall be of certain desired

colors, and with the faces scored or of a rough texture. These bricks are described in the Section *Face and Ornamental Brickwork*. Common bricks are often made or selected for color, *fire-flashed* effects and shape, and used for facing brick walls.

11. Pressed Brick.—Pressed bricks are those that have been pressed in a machine, and are usually hard, smooth, and have sharp corners and true shapes. They are used as face brick.

12. Firebrick.—Firebricks are made from fireclay and are used for lining furnaces, lime kilns, fireplaces, and chimneys in factories. They are usually somewhat larger than ordinary building bricks, and should be of homogeneous composition and texture, uniform in size, of a regular shape, easily cut, and not fusible. The best firebricks are hand-molded.

13. Paving Brick.—Paving bricks are usually made by the stiff-mud process, being repressed to give them a better shape, and are composed of about three parts of shale clay to one part of fireclay. They are burned at a high temperature to the point of vitrification, that is, to a heat at which they begin to fuse or melt. These bricks have a high crushing strength and absorb very little moisture. They are used principally for paving driveways, and occasionally for paving flat roofs on fireproof buildings.

14. Hollow Brick.—Hollow bricks are made of a stiff-mud mixture by machinery, as holes must be formed in the body of the brick. Hollow bricks are now being made more generally by manufacturers of terra-cotta tile, as the material and machinery used in manufacturing tile is better adapted to making hollow brick than is the machinery used in brick making.

15. Sand, or Sand-Lime, Brick.—The composition of **sand brick** is usually 95 per cent. of sand and 5 per cent. of slaked lime. This mixture is forced into molds under a very high pressure, and the bricks are removed from the molds and heated with superheated steam. These bricks can be made in

many colors by artificial means, and can thus be used to effect the most pronounced designs. Sand bricks are manufactured by many firms in the United States, some of which make a very good dense brick, while others make an inferior sandy article.

SIZE, WEIGHT, AND QUALITY OF BRICKS

16. Size and Weight.—There is no universally accepted standard size of brick in America, although the American Society for Testing Materials and the Common Brick Manufacturers Association of America have adopted as a standard size for common brick, 8 in. $\times$ $3\frac{3}{4}$ in. $\times$ $2\frac{1}{4}$ in. The dimensions of brick vary with the locality and also with the maker. Bricks taken from the same kiln will vary in size due to the amount of heat to which they have been subjected.

In the New England States, the average size of a common brick is about $7\frac{3}{4}$ in. $\times$ $3\frac{3}{4}$ in. $\times$ $2\frac{1}{4}$ in.; New York and New Jersey bricks will run about 8 in. $\times$ 4 in. $\times$ $2\frac{1}{2}$ in.; and the walls laid in them will measure about 8, 12, 16, and 20 inches in thickness for 1, $1\frac{1}{2}$, 2, and $2\frac{1}{2}$ bricks. Some of the western common bricks measure $8\frac{1}{2}$ in. $\times$ $4\frac{1}{8}$ in. $\times$ $2\frac{1}{2}$ in., and the thickness of the walls measures about 9, 13, 18, and 22 inches for thicknesses of 1, $1\frac{1}{2}$, 2, and $2\frac{1}{2}$ bricks. On the seacoast of some of the Southern States, the bricks will average 9 in. $\times$ $4\frac{1}{2}$ in. $\times$ 3 in.

The weight of bricks varies considerably with the material used in their manufacture and also with their size. Common bricks will average about $4\frac{1}{2}$ pounds each.

17. Quality.—All bricks should be of uniform dimensions, free from twists, cracks, and pebbles, and should have sharp corners. The bricks should be well burned but not vitrified lest they become brittle. When two bricks are struck together, they should emit a metallic ring. A good brick will not absorb over 10 per cent. of its weight of water if allowed to soak for 24 hours.

COLOR OF BRICK

18. The color of brick is usually not considered of any importance in common brickwork, but as walls of this kind of brick are sometimes exposed to view, the selection of bricks as to color and shade may be desired and consequently the architect's specifications should clearly state if this selection is required.

The color of common bricks depends largely upon the kind of clay used in making them and the temperature attained in the kiln during the burning.

Bricks burned in down-draft kilns are more uniformly burned and are consequently of a more uniform red color.

BRICKWORK

GENERAL DISCUSSION

19. Definition.—By the term *brickwork* is meant any construction made of bricks laid up in mortar. It can readily be seen that the strength of brickwork is not dependent on the strength of the brick alone. Other factors influence this, such as the strength of the mortar and the method of laying up and bonding the brick. Therefore, the value of brickwork, so far as strength and stability is concerned, may be decreased by the use of inferior mortar or by being laid by a bricklayer who does not understand his trade.

20. Importance of Mortar.—In laying bricks, it is customary to bed them in mortar. The mortar serves several purposes. It tends to make the wall waterproof and air-proof under ordinary conditions; it forms a cushion to take up the irregularities in the bricks and thus distributes the pressure evenly, and it bonds the whole wall into one solid mass, which increases its strength and stability.

Mortar for brickwork may be made of various combinations. It may be formed either of slaked or hydrated lime and sand in

proper proportions, or of lime and sand mixed with a small quantity of cement. It may also be made of cement and sand, or cement and sand to which a small percentage of slaked or hydrated lime is added. Lime mortar is, however, to be avoided in work coming in contact with earth or subject to dampness. Mortars of various kinds and qualities are more fully discussed in the Section *Limes, Cements, and Mortars*.

21. Size of Mortar Joints.—With soft-mud or stiff-mud bricks there are likely to be some irregularities which make necessary larger mortar joints than are generally required for pressed brick. For this reason common bricks are generally laid in mortar about $\frac{1}{4}$ inch to $\frac{1}{2}$ inch in thickness.

If a wall is faced with common bricks or bricks that have a rough texture, the joints in the facing are sometimes made as much as $\frac{3}{4}$ inch in thickness and the backing is adjusted either by additional courses of bricks or thicker mortar joints than usual to bring the two kinds of brickwork to the same level, so that they can be bonded together at approximately every six or eight courses in the height of the wall.

STRENGTH OF BRICKWORK

22. Bricks for ordinary requirements are seldom tested for crushing strength, as the masonry formed of well-burned brick laid in good cement mortar will carry all ordinary loads. Bricks should not fail, however, under a crushing load of less than 1,800 pounds per square inch.

The strength of brickwork is influenced by the quality of the brick and the mortar of which it is composed. In cases where the brick is harder than the mortar, the latter is the factor that determines the strength of the brickwork. For this reason the load that may be placed upon brickwork varies with the kind of mortar that is used in its construction. These allowable loads are stated in the building laws in various localities. Local building laws should therefore be consulted when determining the loads on walls of buildings that come under the jurisdiction of such laws. Where no such laws exist, the Building Code

recommended by the National Board of Fire Underwriters is authority for the statement that 111 pounds per square inch may be taken as a safe load for masonry formed of bricks laid in good lime mortar; 208 pounds per square inch for lime and Portland cement mortar; 208 pounds for natural cement mortar and 250 pounds for Portland cement mortar in the proportion of three parts of sand to one part of cement, of which not more than 15 per cent. of the Portland cement by volume may be replaced by an equal amount of dry hydrated lime.

MEASUREMENT OF BRICKWORK

23. The usual method of measuring brickwork is by the thousand bricks laid in the wall. A customary method of estimating the number of bricks in a piece of brickwork is first to determine the entire area of the face of the wall in square feet, measurements being taken on the outside of the wall, and not on the inside. This is done to offset the extra labor that is required in laying up the corners or angles. The number of bricks is computed approximately from these areas, using the number of bricks to the square foot as shown in Table I. Thus, when using a brick $8'' \times 3\frac{3}{4}'' \times 2\frac{1}{4}''$, laid with a $\frac{1}{2}$ -inch joint, there would be 6.17, or $6\frac{1}{6}$, bricks per square foot for a wall 4 or $4\frac{1}{2}$ inches, or 1 brick, thick; $12\frac{1}{3}$ bricks for a wall 8 or 9 inches, or 2 bricks, thick; $18\frac{1}{2}$ bricks for a wall 12 or 13 inches, or 3 bricks, thick; $24\frac{2}{3}$ bricks for a wall 16 or 17 inches, or 4 bricks, thick, and so on, $6\frac{1}{6}$ bricks per square foot being added for every additional brick in the thickness of the wall. The estimate is then based on the number of thousands of brick, at a suitable price per thousand, including labor and mortar. For example, a wall 24 feet long, 12 feet high and 20 inches, or 5 bricks, thick, would contain $24 \times 12 = 288$ square feet 5 bricks thick. At $6\frac{1}{6}$ bricks this would be $288 \times 5 \times 6\frac{1}{6} = 8,880$ brick.

24. The window and door openings in brick walls should always be deducted. While formerly it was in some places the custom not to deduct openings in estimating brickwork, modern

methods adopted by all careful and efficient contractors include the figuring out with exactness the number of bricks required, as above indicated. This applies with force to the quantity of mortar necessitated for the brick. If walls are built hollow a deduction is likewise made for absence of brick and mortar therein. The same is true of all flues in chimneys, the saving in brick alone paying for the cost of the flue lining which

TABLE I
NUMBER OF BRICKS TO THE SURFACE FOOT FOR
DIFFERENT SIZES OF BRICKS WITH JOINTS
OF VARIOUS THICKNESSES

Size of Brick Inches	Thickness of Joint					
	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$
	Number of Bricks					
$7\frac{1}{2} \times 3\frac{3}{8} \times 2\frac{3}{8}$	7.31	7.08	6.86	6.65	6.45	6.26
$7\frac{3}{4} \times 3\frac{3}{4} \times 2\frac{1}{4}$	7.44	7.20	6.97	6.75	6.55	6.35
$8 \times 3\frac{3}{4} \times 2\frac{1}{4}^*$	7.22	6.98	6.76	6.55	6.35	6.17
$8 \times 4 \times 2\frac{1}{2}$	6.55	6.35	6.16	5.98	5.81	5.65
$8\frac{1}{4} \times 3\frac{3}{4} \times 2\frac{1}{4}$	7.00	6.78	6.56	6.36	6.17	5.98
$8\frac{1}{4} \times 4 \times 2\frac{1}{4}$	7.00	6.78	6.56	6.36	6.17	5.98
$8\frac{1}{2} \times 4\frac{1}{8} \times 2\frac{3}{8}$	6.47	6.27	6.08	5.90	5.73	5.57
$8\frac{1}{2} \times 4\frac{1}{8} \times 2\frac{1}{2}$	6.17	5.99	5.81	5.64	5.49	5.33
$9 \times 4\frac{1}{2} \times 3$	4.92	4.79	4.67	4.55	4.45	4.33

*Standard size adopted by American Society for Testing Materials and The Common Brick Manufacturers' Association of America.

should invariably be used, except in the case of thick walls as mentioned in the articles on *Chimneys and Fireplaces*.

25. In Table I is given the number of bricks required for 1 square foot of face of a wall one brick thick—that is, having a thickness equal to the width of a brick—when laid with mortar joints of different thicknesses and bricks of various sizes.

26. This table will be found useful in estimating the number of bricks in any wall. To find the number of bricks per

square foot of face of a wall of any thickness, find in the table the number of bricks per square foot of face of wall for the size of brick and thickness of joint that are to be used and multiply this number by the number of bricks in thickness of the wall. The result will be the number of bricks per square foot of face of the wall in question.

27. For example, according to the table, if bricks $8\frac{1}{4}$ in. $\times$ 4 in. $\times$ $2\frac{1}{4}$ in. in size are to be used, with mortar joints $\frac{3}{8}$ inch in thickness, the number of bricks per square foot of the face of the wall will be 6.36, if the wall is one brick in thickness; if the wall is two bricks in thickness, it will contain 12.72 bricks; if three bricks thick, 19.08 bricks; if four bricks thick, 25.44 bricks.

It will be observed in Table I that the two $8\frac{1}{4}$ -inch bricks show the same number of bricks per surface foot. The reason for this is that the $8\frac{1}{4}$ - and $2\frac{1}{4}$ -inch dimensions are the only ones that show on the face of the wall. The $3\frac{3}{4}$ - and 4-inch dimensions affect only the thickness of the wall.

28. Labor Required.—The amount of labor required for laying brick is a very uncertain quantity. An average man may lay from 750 to 1,000 bricks per day where the work is somewhat broken up and there are openings, or where the walls are thin. On thick straight walls with few openings a man may lay 1,200 to 1,500 bricks per day.

BRICKLAYING

TOOLS AND METHODS

29. Tools Used in Bricklaying.—The tools that are required in building brickwork are a two-foot rule, a long and a short plumb-rule, a level, a large steel trowel, a small steel trowel, a cutting-out hammer, a bricklayer's set, a brick jointer, wooden gauges for measuring bricks, a mason's linen line, chalk, a pencil, and leather protectors for the hand when laying wet or rough-cut bricks.

30. The **long plumb-rule**, or **plumb**, should be from 3 feet 6 inches to 4 feet long, about $3\frac{3}{4}$ inches wide, and about



FIG. 1

$1\frac{1}{8}$ inches thick, with two plumb-glasses at opposite ends, like those shown at *b* in Fig. 1.

The **short plumb-rule**, or **plumb**, should be from 16 in. to 18 in. long, with one plumb-glass like that shown at *b* in Fig. 1 and one level glass, as at *a* in Fig. 1.

31. In Fig. 1 is shown what is known as a combination plumb-rule and level. It is used in a horizontal position as a level and the level glass *a* indicates when the level is exactly horizontal. It is used as a plumb-rule by holding one edge against the work to be plumbed and observing the level glasses *b*. A plumb-bob may be suspended from either end of the instrument so that it will hang in one of the openings *d*. The work is then tested by holding one edge of the plumb-rule against it and moving the instrument until the plumb-line coincides with the center line on the face of the plumb; then if the work does not coincide with the edge of the rule it is out of plumb or not perpendicular.

32. A simple form of **plumb-rule**, shown in Fig. 2, is made of a piece of board $\frac{1}{8}$ inch thick and 3 or 4 inches in width. The edges of the board and the line *d* are parallel. A plumb-bob *b* is suspended on a cord fastened through the notches at the top of the rule and hangs in the opening *c*. When the edge of the rule is placed against a vertical surface and the line coincides with the middle line *d* on the rule the surface is plumb. A plumb-rule of this description may be easily made and is very accurate but is not so convenient as a rule with level glasses.



FIG. 2

The advantage of the leveling glasses in the plumb-rule is that the wind does not interfere with its action. In the case

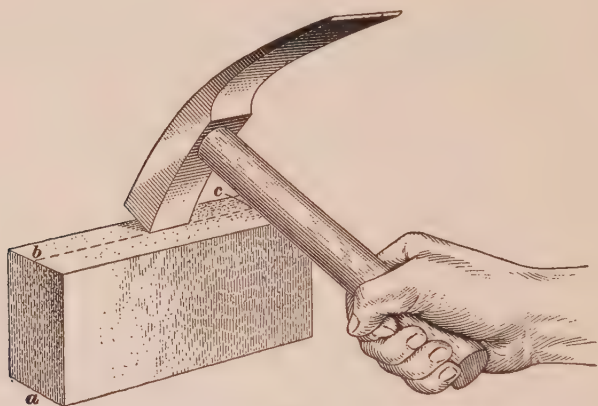


FIG. 3

of a plumb-bob suspended from a cord, even a small breeze causes motion of the bob, which interferes with its usefulness.

33. The principal tool used by a brickmason is the **trowel**, the form and use of which is illustrated further on in Figs. 8, 9, 10, and 11. These trowels are made from $9\frac{1}{2}$ inches to

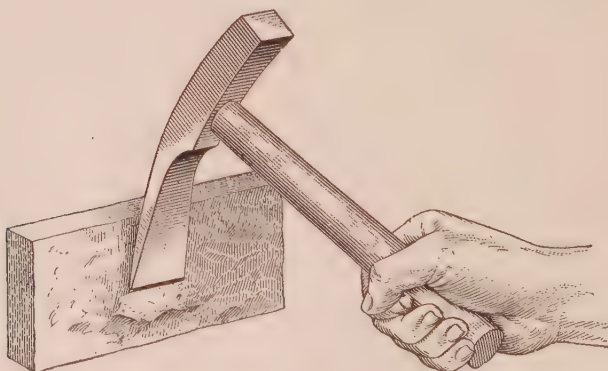


FIG. 4

11 inches in length. Pointing trowels are made from 4 to 7 inches in length.

34. A **cutting-out hammer** should weigh not less than $3\frac{3}{4}$ pounds and not more than 4 pounds, exclusive of the handle. There are many types of hammers that can be used for cutting out, but the one shown in Fig. 3 will enable a first-class man to do the most work with the least fatigue. In this figure is also shown the method of splitting a brick by means of the hammer. A line *a b c* is formed around the brick by means of light blows of the hammer and then a sharp blow is given which causes the brick to split at approximately this line. Any rough places on the split faces of the brick are trimmed off by the blade of the hammer, which is called the *peen*, or *pean*, as shown in Fig. 4.

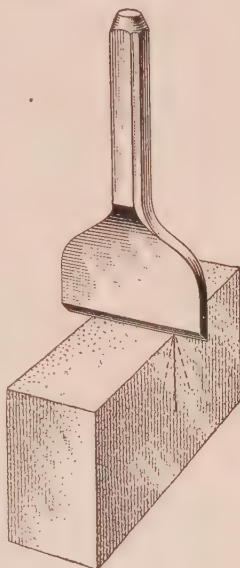


FIG. 5

35. A **brick set**, shown in Fig. 5, is a chisel with a broad cutting edge. It is used when it is necessary to make a cut having straight edges, so that the cut portion may show on the face of the wall, or to make plumb joints with adjacent bricks.

36. A **jointer**, shown in Fig. 6, is a tool that is used to form a true, even, and smooth surface on the face of the mortar between the bricks. Except where common bricks are exposed for effect this tool is not generally used, as the joints of mortar

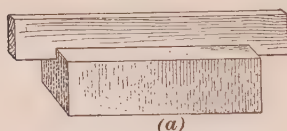


FIG. 6

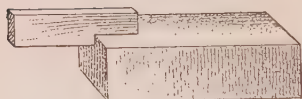
are struck with the trowel as the work progresses; but a brick-mason should possess one for use in connection with such face

effects or face-brick work. Such a tool, at the very best, gets dull and loses its shape quickly, owing to the wearing action of the sand in the mortar, consequently it should be made of the hardest tempered steel that is obtainable. At *a*, *b*, and *c*, Fig. 6, are shown sections through jointers of different kinds. The edges of these jointers are curved or pointed so as to give different profiles to the mortar. The ends *d* and *e* of the jointer may have different sections, so as to be useful for striking two shapes of joints.

37. Wooden gauges, shown in Fig. 7 (*a*), are used to test the lengths of bricks when they are to be selected of a uniform size. The gauge shown in (*b*) is used when it is desired



(a)



(b)

FIG. 7

to cut bricks into smaller sections of uniform length. These tools are used for gauging face brick, but may frequently be used for common brick used in facing walls.

38. The line, chalk, and pencil are familiar but indispensable implements. Pieces of leather, called *leather protectors*, are used by some mechanics to protect their

hands when they are required to handle a great number of bricks daily.

39. Method of Laying Brick.—In connection with the laying of brick, certain terms are used. When a brick is laid with its length in the direction of the wall, as shown at *a* in Fig. 18, it is termed a *stretcher*; a brick placed crosswise so that its end is exposed in the face of the wall as shown at *b* in Fig. 18, is called a *header*. A *course* of brick may mean one horizontal layer of brick or it may mean one horizontal layer of brick and one horizontal mortar joint.

In America, most bricks are laid in what is known as the *American bond*, which is described later in this Section. This bond consists of a layer, or course, of headers and four or five courses of stretchers, then another course of headers, etc. In building brickwork of this kind it is customary to lay the

courses on the outside of the wall first. As many as five or six courses are laid before the bricks forming the inside of the wall are put in place. These outside courses are laid up plumb and level and serve as guides for the courses on the inside of the wall.

40. The first step in laying the wall is to build a portion at each end and see that these are plumb and that the courses at each end are level with the corresponding courses at the other end.

A mason's **line** is then stretched between these ends to serve as a guide in laying the brick in between. In Fig. 8 is shown a mason's line *c d* and the method of attaching it temporarily to

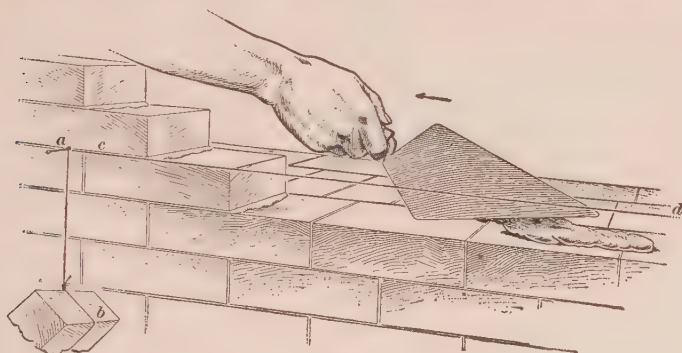


FIG. 8

the wall. This is done by driving a nail *a* into the mortar joint and winding the line around this once or twice. The line is held taut by tying a piece of brick *b* to the end. The line is secured in a similar manner to the corresponding course at the other end of the wall and bricks are laid in between so that their upper edges coincide with the line. By this method the wall is kept plumb and the horizontal joints straight and level.

When the work is interrupted for any length of time, the outer courses should not be higher than the backing, especially where face brick is used, as the mortar joints in the face of the wall will dry out too rapidly and the color of the mortar will appear different from that in other parts of the face of the wall.

41. In Fig. 8 is shown the actual process of laying brick in a 16-inch or 17-inch wall. A trowel with mortar on it is moved

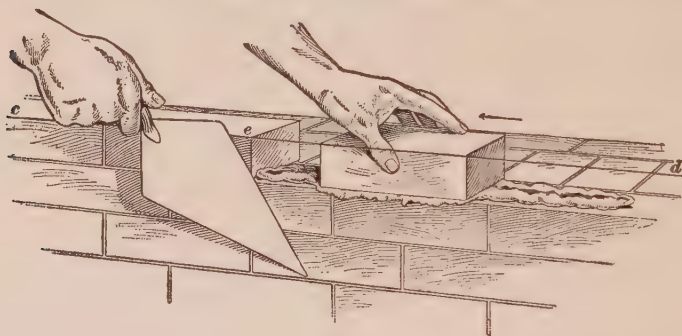


FIG. 9

over the wall in the direction of the arrow and at the same time is tilted so as to allow the mortar to slide off. This distributes the mortar over the outer course of brick in the wall. The mortar is then spread with the point of the trowel, which is drawn through the mortar with a vibrating motion of the hand which causes the mortar to form little ridges as shown in Fig. 9. A brick is then placed on this mortar bed about 3 or 4 inches away from the brick against which it is to be placed, as shown in Fig. 9, and is shoved into place as in Fig. 10. The shoving movement forces a quantity of mortar up into the vertical

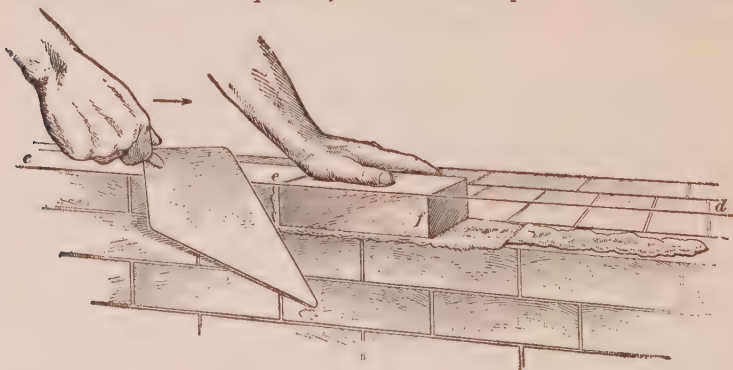


FIG. 10

joint *e*, Figs. 9 and 10, and squeezes out any excess of mortar that may be in the joints.

The upper edge of the brick should coincide with the line *c d*, which is the mason's line previously referred to. If this edge is too high, the brick is tapped down with the handle of the trowel or sometimes with the hammer until it is even with the line. If the top of the brick is below the line, the brick must be taken up and more mortar placed under it.

When the brick has been accurately placed, all the mortar which has been squeezed out while placing the brick and which projects beyond the face of the wall is removed by a stroke of the trowel as indicated in Fig. 10. This surplus mortar adheres

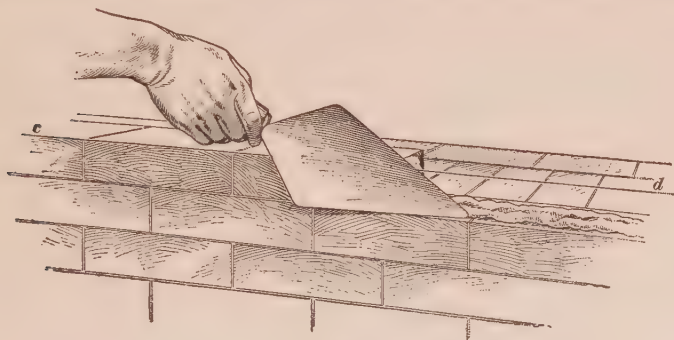


FIG. 11

to the trowel and is scraped off against the vertical edge of the brick as shown in Fig. 11.

42. After five or six courses have been laid on the face of the wall, the joints are all smoothed with a trowel, then the interior of the wall back of these face courses is begun.

The inside course is first laid in the manner described for the face courses and the mortar joints on the inner face of the wall are smoothed with the trowel. A bed of mortar is then placed between this course and the outer course and bricks are placed in the space quite rapidly, as it is not necessary that they be exactly placed. Bricks that are slightly chipped, warped, or that have slight defects are used in the heart of the wall with satisfactory results. Mortar is then filled in between these bricks from the top and another row, or course, is placed on top of the one just finished. Very often the joints in the interior of a brick wall are not completely filled with mortar, and where

the wall does not bear a heavy load this kind of work may be sufficient. In the case of piers and portions of wall that support great loads, it is necessary that all the interior joints in the wall be well filled with mortar.

43. Frequently, instead of laying the bricks on the outside of the wall with a shoved joint, as illustrated in Fig. 9, the bricks are laid right in place, as shown in Fig. 12, with only a small amount of mortar between their ends, such as has been scraped off the trowel. This joint should be afterwards filled by throwing mortar into the top of it from the trowel.

44. Laying Brick in Severe Weather.—When brickwork is erected in freezing weather, all the materials, as far as

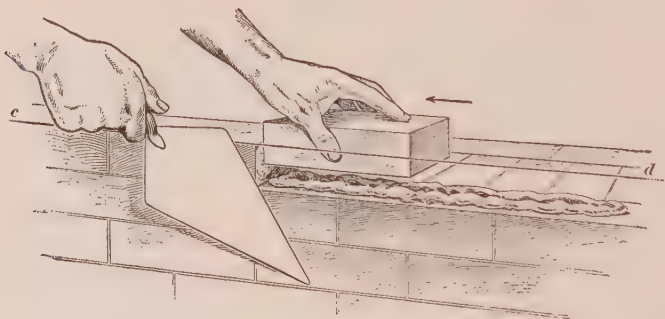


FIG. 12

possible, should be warmed. The brick should be thoroughly dry and in addition should be heated. The mortar should be warmed by using hot water and heating the sand. The scaffold and the wall may be enclosed in tarpaulins, which are large sheets of heavy cotton cloth, and inside the tarpaulin enclosure fires may be kept burning in salamanders, which are sheet-iron cylinders supported on iron legs.

The work should be carefully protected at night by coverings of boards or tarpaulin and should be protected from snow and rain until the mortar has thoroughly set.

Salt is sometimes added to the water with which the mortar is mixed, to prevent its freezing until a very low temperature occurs. The salt, however, is apt to appear later on the face of

the wall in the form of a white efflorescence which disfigures the wall.

In very hot weather the brick should be thoroughly wet with water sprayed on them from a hose. If this is not done, the brick will absorb water from the mortar, which will prevent its setting.

SCAFFOLDING

45. Inside Scaffolding.—In erecting brickwork it is necessary to build scaffolding as the work progresses. The contractor naturally uses the cheapest type of scaffold that will serve his purpose, and will always use an inside scaffold instead of an outside one if the character of the work will permit. The reason is that the floorbeams can then be used to support the scaffold and the scaffold will not have to be built up from the ground.

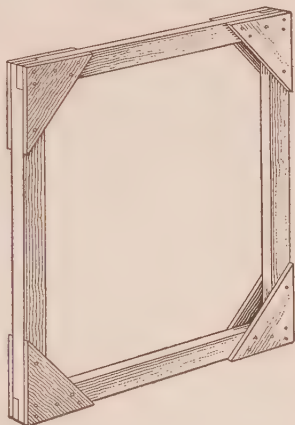


FIG. 13

46. When a simple job of brickwork is to be done, such as a plain building, the bricks are generally laid from the inside so that the inside scaffold can be used. Boards laid upon the floorbeams serve as a scaffold for the wall up to a height of about 4 feet 6 inches. A scaffold consisting of wooden horses with planks laid upon them serves for laying the upper half of the wall of the story. This process is then repeated, the same horses and planks being used over again.

47. Instead of wooden horses, square wooden frames, Fig. 13, braced at the corners, are often used. These are placed in an upright position and braced with boards placed diagonally. Planks are then placed on top of these frames.

48. Exterior Scaffolds.—Exterior scaffolding must be used when the outside face of a wall is to have an ornamental character or be trimmed with cut stone or terra cotta.

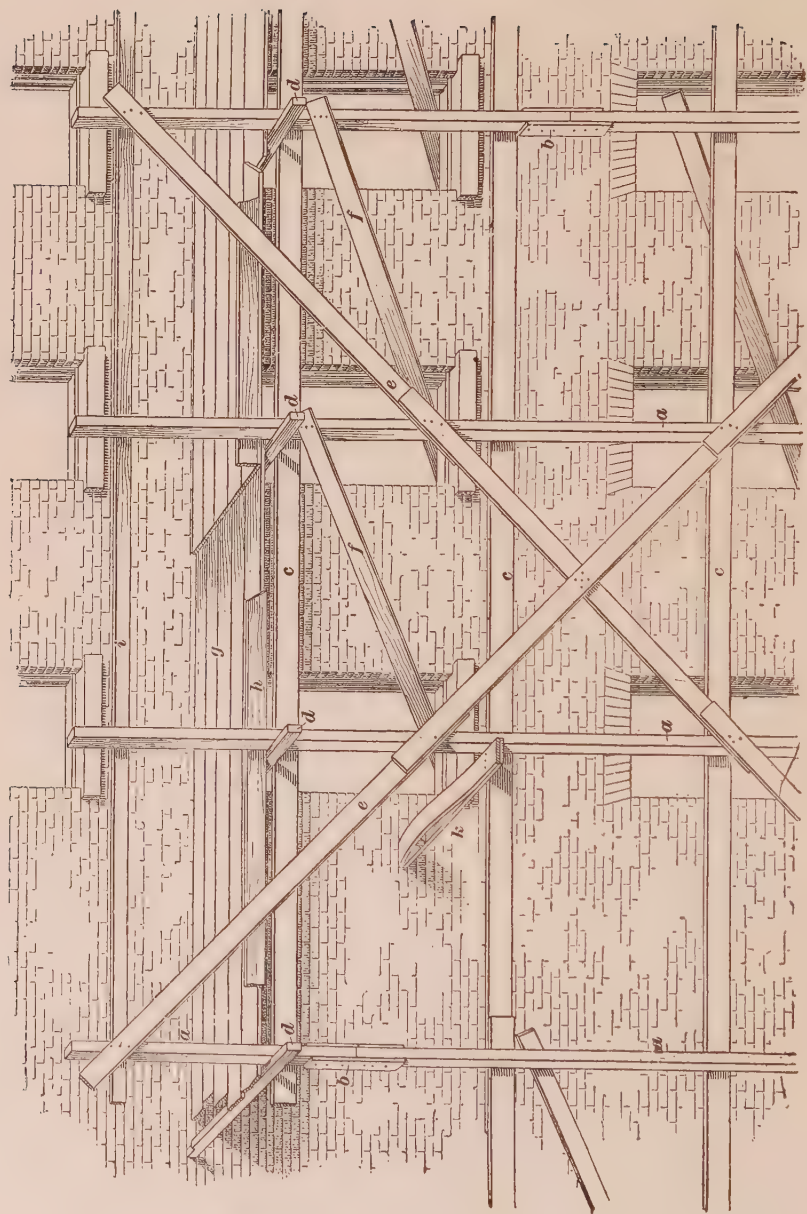


FIG. 14

The most common form of scaffolding used by masons is the **pole scaffold**. There are two types of the pole scaffold. One type depends partly upon the wall for support and the other type is built so as to be self-supporting and independent of the building.

A scaffold that receives some support from the wall is illustrated in Fig. 14. This scaffolding consists of uprights or poles *a*, which may be circular in cross-section, but which are generally in the form of small timbers, having a cross-section of 3 in.×6 in. for a five-story building and never less than 3 in.×4 in. The poles should be placed about 5 feet away from the face of the wall and about 7 feet 6 inches apart on centers. They should be firmly supported on the ground, and the lower ends should be braced so they will not slip. When they must be spliced together to make them longer, they are placed end to end and a piece of plank is nailed on each side of the joint as shown at *b*. These splices should not occur in all the poles at the same level. Ledger boards *c* are nailed to the poles to brace them horizontally and also to support the putlogs *d*, which sustain the floor of the scaffold. The other end of the putlog extends into the wall 4 or 5 inches. The uprights are braced diagonally by the braces *e* and to window frames by the window braces *f*. These latter braces prevent the scaffolding from falling away from the building.

What is known as a **spring stay** is shown at *k*. This device consists of two boards or planks, the ends of which are placed in a hole in the wall and a block is placed between them near to the wall. The block causes the boards to spread. The spread ends are brought together and nailed to the ledger. This action forces apart the ends in the wall so that they obtain a firm grip in the wall. The spring stay holds the scaffold firmly to the wall.

A platform *g*, formed of 2"×10" planks, which lap over each other at the ends, is laid on the putlogs. Foot-boards *h* are nailed on top of the platform against the uprights, also a guard-rail *i* is placed at a suitable height.

The entire structure should be thoroughly braced and well nailed with 10- or 12-penny nails.

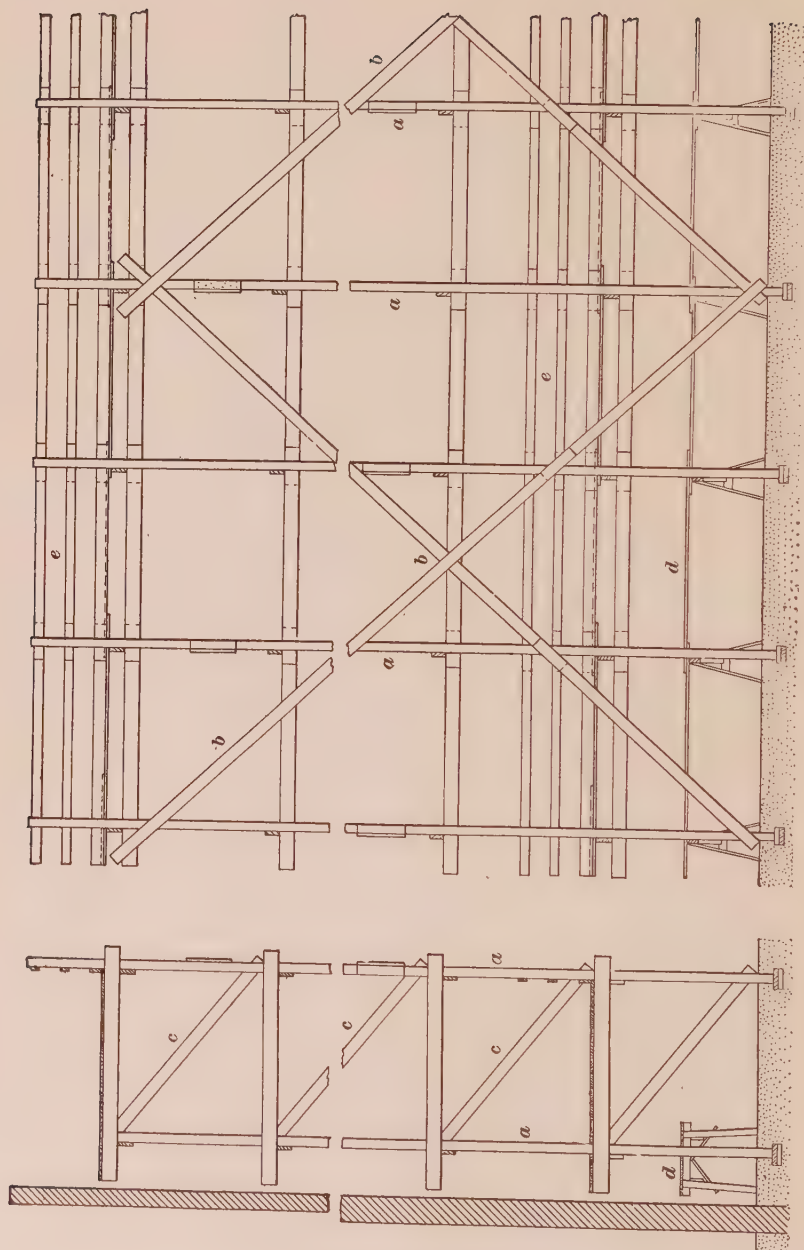


FIG. 15

49. A self-supporting pole scaffold is shown in Fig. 15. There are two sets of poles or uprights as shown at *a* in the side view. These are braced together, as indicated at *b* in the front view, as well as in a direction perpendicular to the wall, as at *c* in the side view. The planks of the working platform are carried on horizontal pieces which, as shown, do not touch the building. Putlogs are not used in this scaffold, as their use is likely to disfigure the face of the wall. It is always difficult properly to patch up the holes in the wall made by the putlogs, and for this reason it is desirable to use an independent scaffold. The upper part of the first-story wall is laid from the scaffold *d*, which consists of planks laid on horses. There are two guard rails shown at *e*. A scaffold of this description should not be used for a wall more than 100 feet in height.

50. A type of scaffold that is used when only one story of the wall, such as the cornice story, is required to be built from the outside, is formed by extending planks on edge out of the window openings and laying a platform upon them. Guard rails should be provided as in other scaffolds.

51. Suspended Scaffolds.—On tall, skeleton-construction buildings, suspended scaffolds are used. Steel beams called outriggers are supported on the floorbeams of the upper part of the frame of the building and project out 5 or 6 feet beyond the face of the wall. From these projecting beams the scaffold is suspended by means of wire cables. The cables are attached to the scaffold by means of devices by which the cable can be rolled up and the scaffold thus raised as required.

BRICK WALLS

TYPES OF BRICK WALLS

52. Solid Walls.—The brick wall most universally used and which is cheapest to construct is the *solid* wall. This wall consists of a solid mass of brickwork with no hollow spaces constructed in it. Such a wall is substantial, easy to build, and when properly constructed will last for centuries.

53. There are certain disadvantages characteristic of brick walls, and these result from the porosity of the brick and mortar. Unless a wall is built of good hard-burned brick and laid up with a properly proportioned mortar, moisture is likely to find its way through it. Some method is, therefore, generally adopted to prevent this moisture from reaching the inner surface of the brickwork, especially when plastering is applied directly to the brick.

54. One of these methods is to coat the inner surface of the wall with a damp-proofing compound which fills the pores on the inner surface of the wall and adheres strongly to the brickwork. At the same time this compound affords a good key for the plastering.

Another method is to form the inside 4 inches of hollow bricks or 8 inches of hollow tile, but while plastering applied directly to these surfaces will hold satisfactorily, the bonding courses of the joints are apt to become damp on the inside during wet weather.

55. The best and cheapest method of preventing water from reaching the plaster is to furr the walls. This may be done by nailing wooden **furring strips** about 1 inch by 2 inches in size to the inner face of the wall and nailing wood or metal lath to them to receive the plastering. Metal rods or furring may be stapled to the walls and metal lath fastened to them, or one of the several types of *self-furring* metal laths may be used. Terra-cotta furring may be applied to the entire face of the wall, such furring being held in place by the use of mortar and nails.

56. Hollow Walls.—Hollow walls, or more properly, double walls, are sometimes built and are intended to keep moisture from passing through, and by providing a complete separation of one wall from the other, keep the building cooler in summer and warmer in winter. Difficulties that largely offset their advantages are met with in construction, however, so that hollow walls are not often used in the United States. The objections to hollow walls are that more ground area is

required, thicker foundations are needed, the cost of construction is increased, and there is no assurance that the two walls are better than one solid wall properly furred.

57. Party Walls.—A **party wall** is a wall that separates two adjoining buildings and carries the floor and roof beams of both of them. The floor loads on party walls are twice as great as the load on any outside wall.

Building regulations in regard to the thickness of party walls are based on the span of the joists or width of building, and on the height. The specifications of the Committee on Building Construction of the National Fire Protection Association require all party walls and fire walls to be of solid masonry and almost all building codes require solid brick, not only as fire protection but to afford the property owner on each side the opportunity to insert or hang joists at any desired level or place.

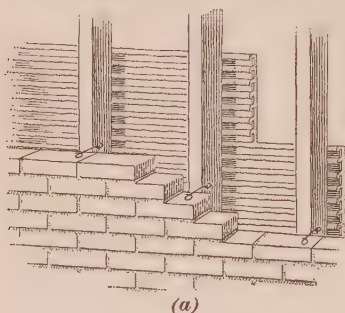
58. Fire Walls.—The National Fire Protection Association has defined a fire wall as follows: "The term **Fire Wall** indicates a wall subdividing a building to restrict the spread of fire. In all buildings it shall start at the foundation, be continuous through all stories and extend at least 3 feet above the roof."

59. Panel or Enclosure Walls.—In modern skeleton construction, the floor loads in a building are carried on the steel or reinforced-concrete frame, and the walls carry no load other than their own weight. Such walls are generally supported upon girders extending from column to column, usually at every floor. In this way much thinner walls can be used, and valuable space can be saved.

The New York City Building Code provides that "masonry walls supported at each story by girders may be 12 inches thick for the entire height of the building."

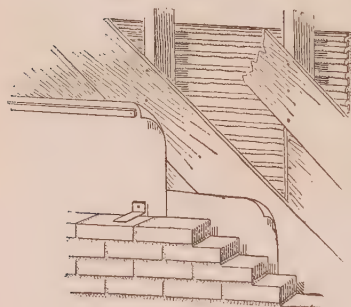
The Chicago building ordinances provide that "If buildings are made of fireproof construction, and have skeleton construction so designed that their enclosing walls do not carry the weight of floors and roof, then their walls shall be not less than 12 inches in thickness."

60. Curtain Walls.—Following is an extract in regard to curtain walls from the New York City building laws:



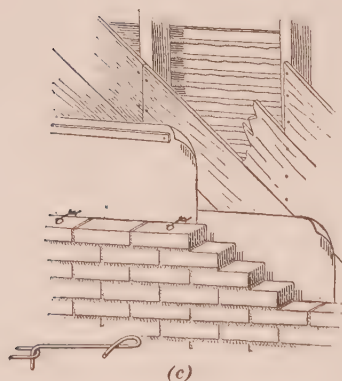
(a)

"Curtain Walls. Non-bearing walls built between piers or metal columns shall not be less than 12 inches thick for the uppermost 60 feet of height, increasing 4 inches in thickness for each next lower section of 60 feet." Curtain walls are not supported by beams, but rest on suitable footings supported on the foundation soil.



(b)

61. Veneered Walls. Frame houses are frequently incased in a 4-inch veneer of brick, separated from the wood by a 1-inch or a 2-inch air space. Veneered walls are generally somewhat cheaper than those built of solid brick. Houses constructed in this fashion are warmer in winter and cooler in summer, and are also less likely to catch fire from outside sources than are ordinary frame buildings.



(c)

FIG. 16

62. In building a house with veneered walls, the foundation must project far enough beyond the line of the studs to carry the brickwork that is put on later. This requires a projection of 1 inch for sheathing, 1 or 2 inches for air space, and

4 inches for brick. The 1 or 2 inches allowed for an air space is also necessary to accommodate the mason's fingers

when he is laying the brick, and is frequently called a *finger space*.

Care must be taken to construct the frame in the best manner, for the brick veneer carries absolutely no part of the building except its own weight, and in fact has to be tied to the wood framing for support. After the frame is up it should be sheathed diagonally and the sheathing should, as a rule, be covered with tar paper or other waterproof material on the

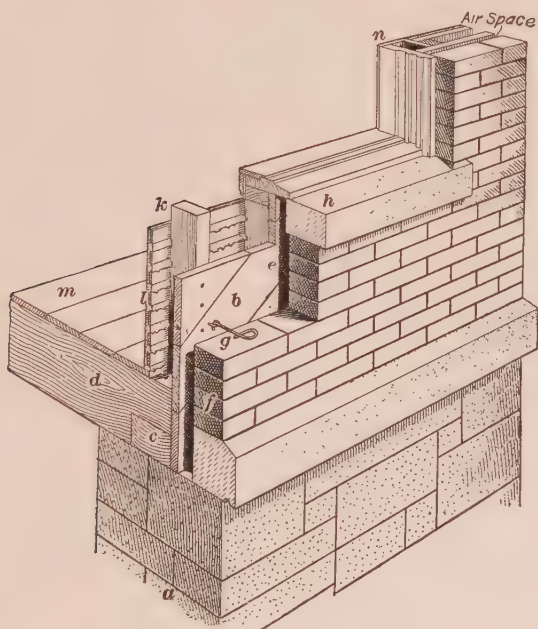


FIG. 17

outside before the bricks are laid. The sheathing is omitted in a very cheap form of construction such as is shown in Fig. 16 (a). This form of construction is not to be recommended, however. The tar paper is omitted in Fig. 17 for the sake of clearness. All the framing timber, particularly the sills, should be as dry as possible, and the frame must be perfectly plumb and straight; if not, the brick veneer will not lay up properly.

The brick veneer is usually tied to the diagonal sheathing or

to the studs with metal ties. The wire tie, shown in Fig. 16 (*a*) and (*c*), is most generally used, though a tie made of No. 16 iron, $1\frac{1}{4}$ inches wide, with the end turned up, as shown in Fig. 16 (*b*), gives satisfactory results. The ties are generally placed on every other brick in every fifth course of brickwork.

63. Fig. 17 shows a section through part of the foundation of a veneered building and the principal features of its construction. At *a* is shown the stone foundation wall, projecting 6 inches beyond the diagonal sheathing *b*; the 4"×6" sill is shown at *c*, the 2"×10" floor joists at *d*, and the air space between the brickwork and the sheathing at *e*. The 4-inch brick-veneer wall is shown at *f*, and the wire tie at *g*; the stone window sill is shown at *h*, the 2"×4" studding at *k*, the lathing at *l*, the flooring at *m*, and the window frame at *n*.

Due to the fact that any stability which a 4-inch brick veneer receives is dependent upon metal ties, which may rust, attached to a wooden building which may vibrate and will burn, this type of construction is not to be recommended, especially for any height above two stories.

64. Veneering on Hollow Tile.—Brick, especially face brick, may be used as a veneer on hollow building tile or back-up blocks. A wall of this description is generally damp-proof, and plastering can be applied to the inside face of the terra cotta without the danger of dampness affecting it. Such walls will be more fully described later in the Section on *Hollow Tile*.

THICKNESS OF WALLS

65. The thickness of walls in brick masonry is a matter that cannot be determined by calculations. Experience must be followed and also the regulations laid down in the building codes of different cities. The latter is the better plan, as the stipulations given in these codes are the result of experience of many men, and there are thousands of buildings to show the successful application of the rules given in these codes.

66. According to the New York City Building Code.—The New York Building Code makes the following

provisions for structures where the walls are entirely of brick and support the floors and roofs, and where no steel columns or beams are built into the walls:

Residence Buildings.—Except as otherwise provided, the thicknesses of brick walls of residence buildings hereafter erected shall be not less than the following: (a) When over 75 feet in height, 12 inches for the uppermost 25 feet, 16 inches for the next lower 35 feet, 20 inches for the next lower 40 feet, with a 4-inch increase for each additional lower section of 40 feet; (b) when not over 75 feet in height, 12 inches for the uppermost 55 feet, and 16 inches below that.

Public and Business Buildings.—Except as hereinafter provided, the thickness of masonry (brick) walls of public and business buildings hereafter erected shall be not less than the following:

(a) When over 75 feet in height, 16 inches for the uppermost 25 feet, 20 inches for the next lower 35 feet, 24 inches for the next lower 40 feet, and increasing 4 inches for each additional lower section of 40 feet.

(b) When over 60 feet and not over 75 feet in height, 16 inches for the uppermost 50 feet, and 20 inches below that.

(c) When over 40 feet and not over 60 feet in height, 12 inches for the uppermost 20 feet, and 16 inches below that.

(d) When not over 40 feet in height, 12 inches throughout.

Increased Thickness When Required.—(a) Every bearing wall with face brick bonded with clip courses or ties, and every bearing wall faced with ashlar, shall have a total thickness of at least 4 inches more than otherwise required unless the ashlar is at least 8 inches thick in every alternate course and bonded to the wall:

(b) When the clear span between bearing walls is over 26 feet, such walls shall be increased 4 inches in thickness for every $12\frac{1}{2}$ feet or part thereof that said span is over 26 feet.

(c) All walls over 105 feet long between cross-walls or proper piers or buttresses, shall be increased in thickness over the minimum requirements at least 4 inches for every 105 feet, or part thereof, over 105 feet in length.

(d) If the horizontal section through a bearing wall shows more than 30 per cent. area of flues and openings, such part of the wall where the excessive openings exist shall be increased 4 inches in thickness over minimum requirements for every 15 per cent. or fraction thereof, of flue or opening area in excess of 30 per cent.

General Reservations.—Nothing in these laws shall prevent the use in any wall of the same amount of material in piers and buttresses as is required for the thickness prescribed.

The unsupported height of any wall or part thereof shall not exceed 20 times the thickness of such unsupported part, unless reinforced by adequate cross-walls, buttresses, or columns.

67. According to the Chicago Building Ordinances.—The ordinances of Chicago group buildings into several classes and specify certain conditions that apply to these different classes. Where the walls of the buildings are entirely of masonry and support the floors and roof, the following general regulations are prescribed:

Brick, stone, and solid concrete walls, except as otherwise provided, shall be of the thickness in inches indicated in the following table:

Number of Stories in Building	Story												
	Basement	1	2	3	4	5	6	7	8	9	10	11	12
	Thickness of Wall, in Inches												
One.....	12	12											
Two.....	16	12	12										
Three....	16	16	12	12									
Four.....	20	20	16	16	12								
Five.....	24	20	20	16	16	16							
Six.....	24	20	20	20	16	16	16						
Seven....	24	20	20	20	20	16	16	16					
Eight....	24	24	24	20	20	20	16	16	16				
Nine.....	28	24	24	24	20	20	20	16	16	16			
Ten.....	28	28	28	24	24	24	20	20	20	16	16		
Eleven..	28	28	28	24	24	24	20	20	20	16	16	16	
Twelve ..	32	28	28	28	24	24	24	20	20	20	16	16	16

There are modifications in these thicknesses that may be made under certain conditions, and when building where this code is in force a copy of the ordinances should be obtained and carefully followed. For instance, certain provisions are made for the use of 8-inch or 9-inch walls in dwellings and other small buildings, and these and other provisions must be complied with where such laws are in force.

BOND IN BRICKWORK

68. Necessity for Bond.—To build a strong, substantial, and solid wall with such small pieces of material as bricks, requires a careful arrangement of the bricks in the body of the wall so that they shall be tied together and form a cohesive mass of masonry. Tying the bricks together is done partly by good mortar and largely by proper bonding. **Bonding** may be described as the process of laying bricks so that one brick shall rest on parts of two or three bricks below it. The *bond* in a wall is the result obtained by *bonding*. Brickwork that is not

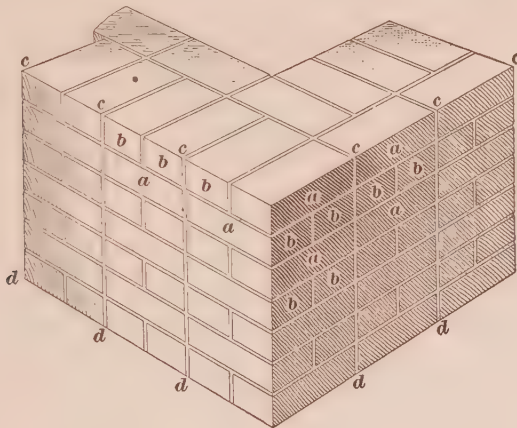


FIG. 18

properly bonded is shown in Fig. 18. By placing the brick in this manner, the wall is merely a series of piers that abut each other on the lines *c*, *d* and have no bond or union between them other than that obtained by the adhesion of the mortar.

The object of the standard bonds, that will be described presently, is to tie the wall together both longitudinally, or in the direction of the length of the wall, and transversely, or in a direction perpendicular to the face of the wall. The best brickwork is that in which the bricks are most thoroughly tied or bonded together, both lengthwise and crosswise, as well as vertically.

69. Terms Used in Bonding.—When brick are laid lengthwise in the face of a wall, as at *a* in Fig. 18, they are termed **stretchers**. When placed crosswise so that their ends are exposed in the face of the wall, as at *b*, they are called **headers**. A **course** means a horizontal layer of brick or one horizontal layer of brick and one horizontal mortar joint. Parts of bricks, that are made by cutting the whole brick, are called **bats** or **closers**. The different bats used in brickwork are shown in Fig. 19. A whole brick is shown in (*a*). When a brick is cut longitudinally, as in (*b*), on the line *a b*, each half is called a **queen closer**. It is difficult, however, to cut a brick in this manner, hence it is first cut on the line *c d e* and

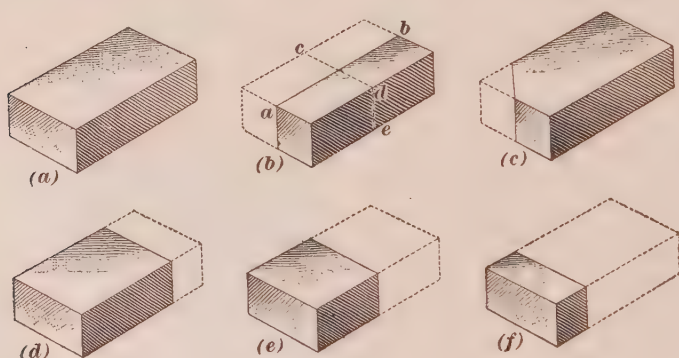


FIG. 19

each half is cut along the line *a b*. When a brick is cut as in (*c*), it is called a **king closer**. When one-fourth of a brick is cut off as in (*d*) the remainder is called a **three-quarter bat**. In (*e*) is shown a **half bat** and in (*f*) a **quarter bat**. A **closer** is a bat used to fill up a space near the end of a wall, resulting from the longitudinal bond used in the wall. Closers are illustrated in Fig. 20 at *c*.

70. Bonding is accomplished by lapping one brick over portions of two or more bricks in the course below. This process is often referred to as **breaking joints**. The vertical joints should not come one above the other in the face of the wall as shown in Fig. 18, but should alternate as shown in Fig. 20. This is done systematically so that the vertical joints shall

occur in plumb lines. The vertical joints in one course should be kept perpendicular, or directly over those in the second course below.

The joints in both faces of the wall should be directly opposite each other. This arrangement of the joints in the top of the wall is shown in Figs. 16, 21, 22, etc.

STANDARD BONDS

71. In the course of time there have been developed several standard methods of bonding brickwork such as the English, Flemish, American, Running, etc. bonds.

72. English Bond.—The **English bond** is probably the best and strongest method of bonding brickwork. In this

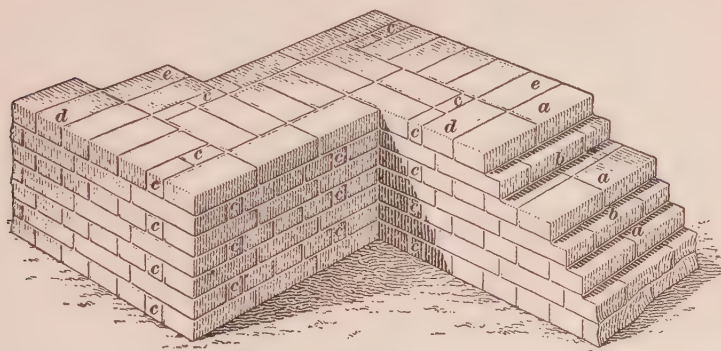


FIG. 20

bond, header and stretcher courses are laid alternately, as shown in Fig. 20. Joints are broken in the longitudinal bond courses by the use of quarter-bat closers, marked *c*. This is without doubt the best and simplest bond to use in all work where strength is required, as by its use a complete and thorough transverse bond is formed. It will be observed that the heart of this wall, which is about 16 inches thick, consists entirely of headers, and that the joints of the header course, as at *a*, are well bonded by the headers *b* of the stretcher course.

73. The wall shown in Fig. 20 has only two different courses. The arrangement of the bricks in these courses is

shown in Fig. 21 in courses *A* and *B*. By studying these plans in connection with Fig. 20 there should be no difficulty in understanding the construction of the wall. At *c* are shown

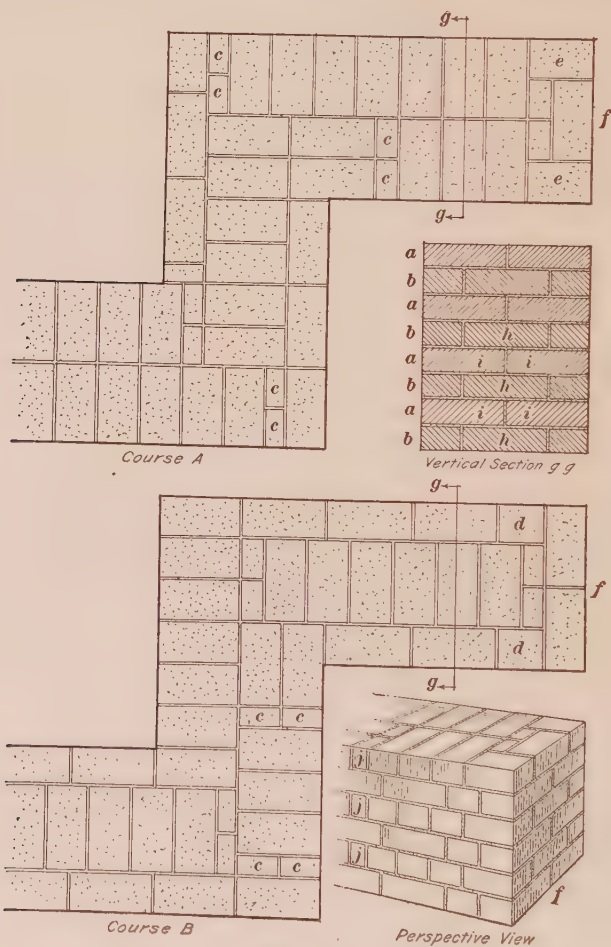


FIG. 21

queen closers; at *d*, half-bats; and at *e*, three-quarter bats. These latter are used in forming the end *f* of the wall.

In the vertical section through the wall taken through *g g* are shown the cross-ties formed by the bricks *h* lapping over

the bricks *i*. The perspective view shows the arrangement of the bricks in the face of the wall. The closers are shown at *j* and the end of the wall at *f*.

74. Flemish Bond.—The **Flemish bond** is one in which each course is composed of alternate headers and stretchers. The method of laying the bricks in this bond is illustrated in Figs. 22 and 23. Bats *a* and *b* are used at the corners of the walls and at *c* on the interior of the wall. In this example the headers and stretchers on the inner face of the wall are exactly opposite those on the outer face, and the wall is said to be built in **double Flemish bond**. The vertical section is taken through *e e* on the plans of the courses

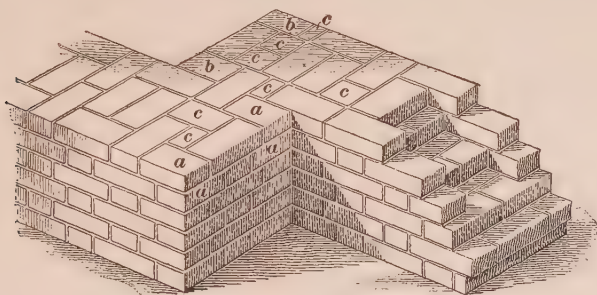


FIG. 22

A and *B* and shows the bond. The perspective view shows the appearance of the bond in the face of the wall and the jamb *f*.

75. American, or Common, Bond.—The bond most extensively used in the United States is known as the **American, or common, bond**. It is, in fact, a modification of the English bond. Instead of making every other course of brick a header course, as in the English bond, every fifth, sixth, or seventh course is made a header course in the American bond, with stretcher courses in between. This construction is illustrated in Fig. 24. Plans of the different courses are shown in Fig. 25, in which (*a*) and (*b*) are the courses that form the cross-bond, and (*c*) and (*d*) the stretcher courses in between. The arrangement of these courses is shown in the vertical sections (*f*) and (*g*).

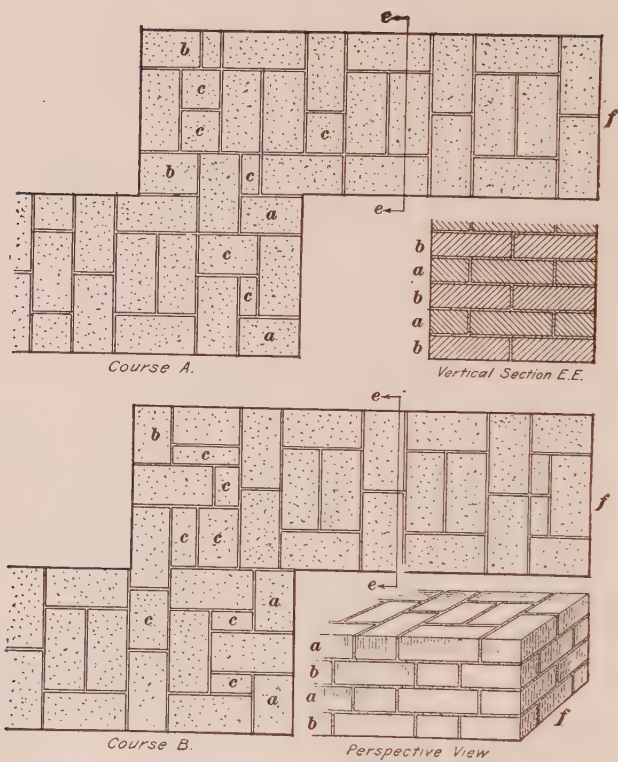


FIG. 23

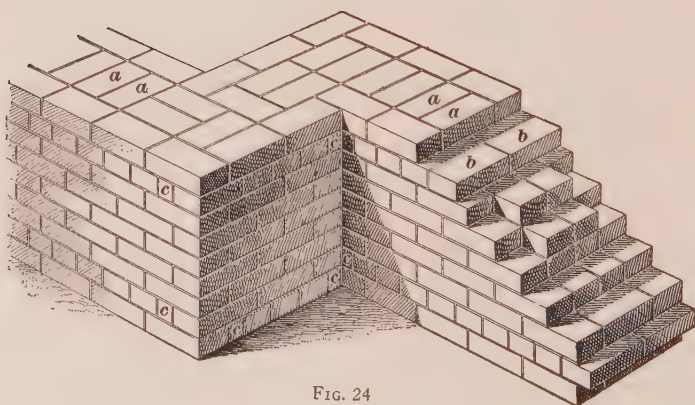


FIG. 24

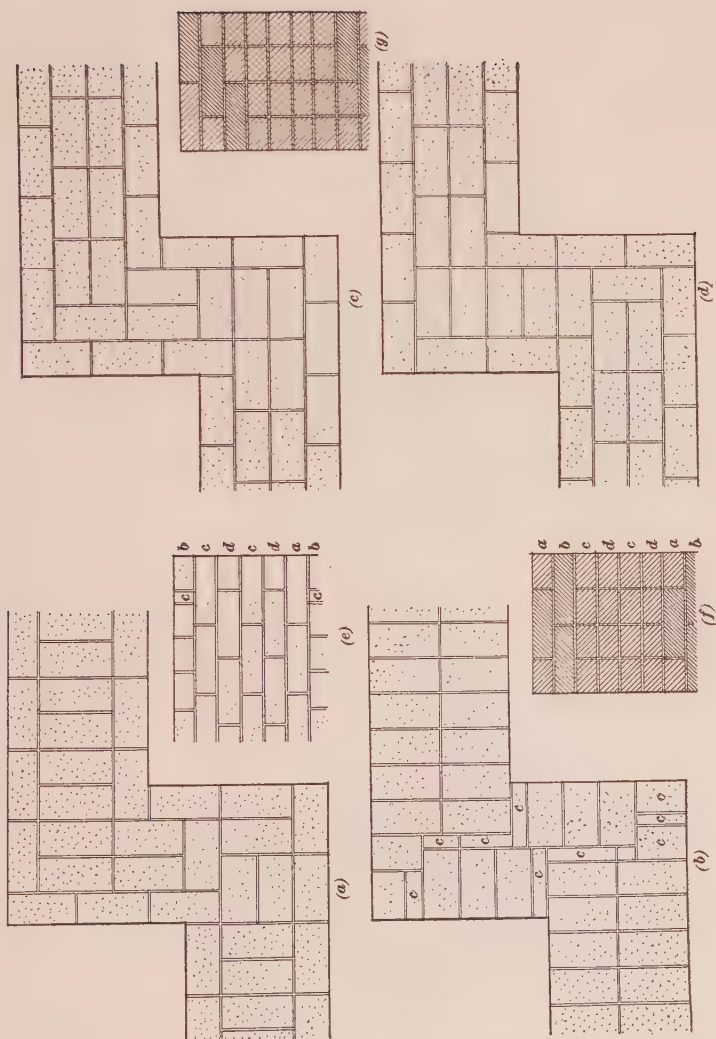


FIG. 25

The bond shown in (f) is formed by the two header courses *b* placed at the same level on the outside and inside faces and a course *a* lapping over both headers. This treatment brings the heading courses at the same level on both sides of the wall.

In (g) is a slightly different arrangement which is often used. In this case the header course on one side of the wall is lower than the header course on the other side.

The courses (a), (b), (c), and (d) are laid out according to the section (f). The arrangement of the bricks in the face of the wall is shown in (e). This form of bonding makes a wall that can be quickly and therefore cheaply built.

76. American bond is generally used in the United States not only for building walls of common brick, but also for backing up terra cotta, stone, and face brick. In fact the backing up is the real wall that not only supports the floor and roof loads, but also the weight of the facing.

The New York building laws require that every sixth course shall be a header course; that is, that five courses of stretchers must come between two courses of headers. For factory and warehouse purposes, where the walls have to sustain heavy weights, it is better to have every fourth course a header course, thus giving three courses of stretchers between the header courses.

BONDING FACE BRICK

77. Stretcher or Running Bond.—When a facing of brick is applied to a wall of common brick it is necessary to tie the facing firmly to the *backing*, or common-brick wall. This is done in different ways. When the facing is in running or stretcher bond there are no headers appearing in the face of the wall. In this case galvanized metal ties are generally used as shown in Fig. 26.

78. Face Bonds.—English and Flemish as well as other ornamental bonds are often used as facings only and are secured or bonded to a wall that is laid up in American or common bond. This can easily be done by extending some of

the numerous headers of the face bonds into the backing and thus securing an ample tie. The remaining headers will be composed of half-bricks or bats.

79. Metal Ties for Brickwork.—Fig. 26 illustrates the method of bonding in face brick with steel or galvanized-iron

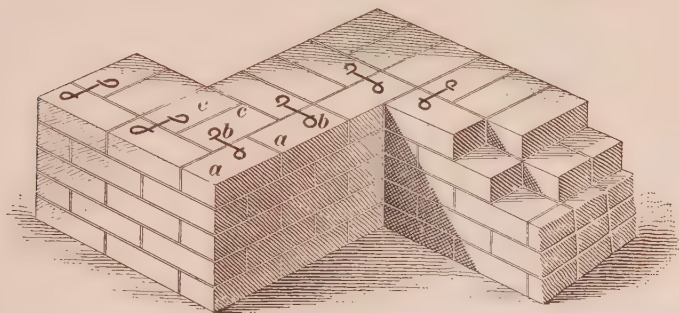


FIG. 26

wire. These wire ties *b* are twisted at the ends, and hold together the inside and outside courses *a* and *c*, as shown. They are laid in every sixth course of brick.

A still better method of tying front brick to the common brick in the rear of the wall is by the use of galvanized steel

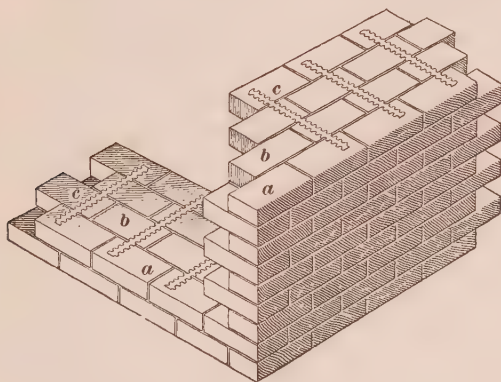


FIG. 27

ties from $\frac{3}{8}$ to $\frac{1}{2}$ inch thick, and having some of the metal punched out. The brick may be brought down to a very close joint, and the clinching edges make a very firm and satisfac-

tory binder. Fig. 27 shows the application of these bonding strips. Here, *a* is the pressed-brick facing, *b* the common brick in the rear of the wall, and *c* the steel ties bonding the pressed brick to the common brick.

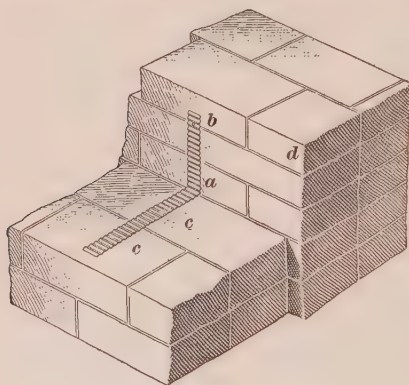
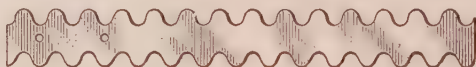


FIG. 28

Similar ties can be used for tying a new wall to an existing wall to increase its strength. The tie is bent near the middle, as shown at *a* in Fig. 28, and is nailed to the old wall with pointed wrought-iron nails, shown at *b*. These nails have

large flat heads made especially for this work, and are of sufficient size to make a firm connection for the new courses *c*.

Other forms of metal ties that are on the market are shown in Fig. 29. In using such ties it is generally advisable to use those that are sold in the local market.



BONDING HOLLOW WALLS

80. Before the introduction of metal ties, the bond between the two walls which form the hollow or

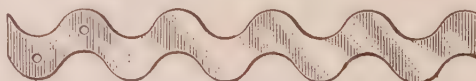


FIG. 29

double wall was accomplished with brick which were embedded in both walls and extended between them, tying them together.

This method was very expensive, as it required considerable cutting of brick. It also reduced the effectiveness of the hollow wall, as it provided places in the bonding brick through which dampness might pass.

81. Bonding With Metal Ties.—Bonding hollow walls by the use of metal ties is the cheaper and probably the better method, provided the ties are thoroughly protected from cor-

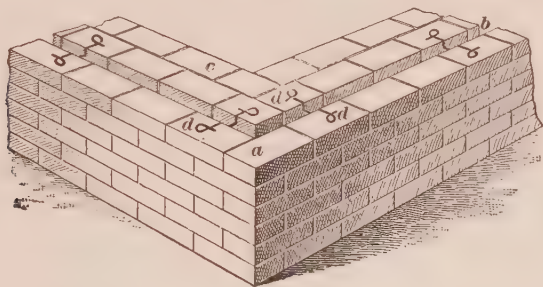


FIG. 30

rosion by galvanizing. These ties make the hollow wall effective, as the ties will not carry moisture to the inner wall.

At *a*, Fig. 30, is shown a 4-inch wall; at *b*, the air space; at *c*, the inner 8-inch wall; and at *d*, the metal ties. It should be said that hollow walls are not built very frequently, as the same results can be obtained at less cost by using hollow terracotta tile, called back-up tile, with a veneering or facing of brick.

BONDING WALLS AT ANGLES

82. In building brick walls, it is necessary that the angles in the walls be properly bonded. When the two walls forming the angle are carried up at the same time, the bonding at the corners is easily effected; if, however, one wall is built first, due to a delay in getting materials required for the other wall, particular care must be taken that the two parts will bond together properly.

In such cases, the wall first built is generally left toothed, as shown in Fig. 31.

In order to unite the two walls more firmly, anchors made of $\frac{3}{8}'' \times 2''$ wrought iron, with one end turned up 2 inches and the other turned around a $\frac{5}{8}$ -inch bar, should be built into the side wall about every 4 feet in height, as shown at *b*,

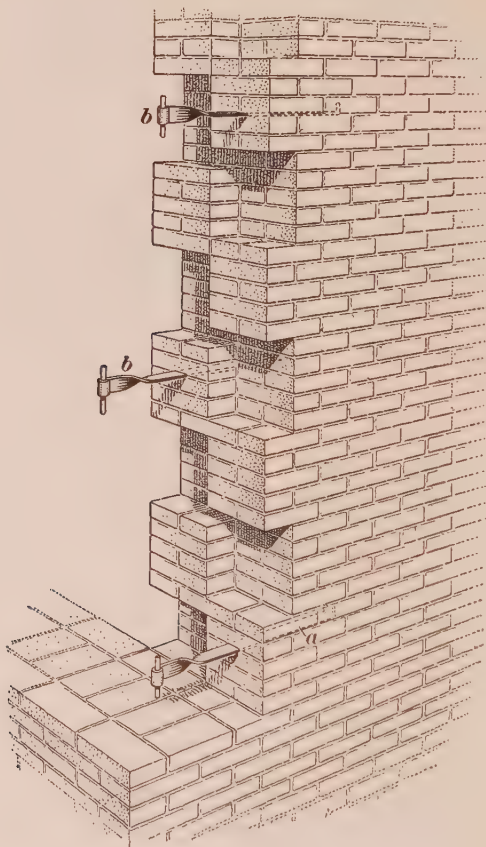


FIG. 31

Fig. 31. These anchors should be long enough to extend at least 12 inches, or the depth of one and one-half bricks laid the long way, as shown at *a*, into the side wall, and the center of the $\frac{5}{8}$ -inch bar should be about 8 inches from the back of the front wall.

JOINING NEW WALLS TO OLD WALLS

83. In joining a new wall to an old, a groove should be cut perpendicularly in the old wall, usually the width of a brick, so as to make a joint; this is called a *slip joint*.

This method of bonding is shown in Fig. 32. At *a* is shown the groove or chase cut where the new wall is to enter in the old wall; *c* is the new wall, and *d* the old wall.

In cheap construction, where new work is bonded into old, the method most commonly used is to nail a piece of

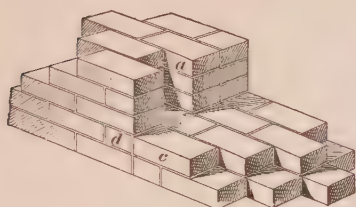


FIG. 32

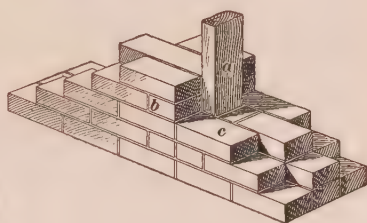


FIG. 33

2"×4" timber against the wall, as shown in Fig. 33, where *a* shows the 2"×4" timber spiked to the old wall and entering the center of the new wall. At *b* is shown the old and at *c* the new wall.

OPENINGS IN WALLS

84. Openings in Solid Walls.—When a brick wall contains door and window openings, their location and relative position should be very carefully considered, not only with regard to convenience and symmetry, but also with regard to their effect on the strength of the wall. When walls are broken frequently by windows and other openings, cracks are more likely to occur than when the wall is plain and unbroken. This is owing to the unequal pressure on the wall. If walls are well bonded and anchored, the danger of cracks will be reduced to a minimum. When possible, the window openings in the different stories should be placed directly over one another.

Unless absolutely necessary, the placing of windows under a pier or directly over a narrow mullion should be avoided. When such a design must be used, brick arches or metal beams, or both, should be built in if the span is great or the arch a *flat* one.

In any bearing wall carrying the ends of floorbeams, the combined horizontal area of openings should not be more than one-third the total horizontal area of the wall, unless the thickness of the wall between the openings is increased by the use of pilasters, or buttresses.

85. Relieving Arches.—Openings may be spanned at the top by means of arches or lintels. Lintels cannot be made

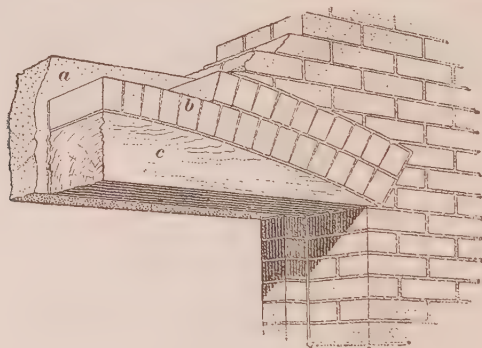


FIG. 34 .

of brickwork and are generally made of stone or reinforced concrete or a combination of metal and brick as described in the preceding article. When stone lintels are used they are generally only 4 inches in thickness and the remaining thickness of the wall must be supported either by steel or by brick **relieving arches**, such as shown in Fig. 34. These arches *b* are built upon solid wooden centers *c*, which are left in place after the arch is completed. The stone lintel is shown at *a*. Bricks laid in the manner shown at *b* are called *rowlocks*, and such arches, being made of two or more rows of rowlocks, are called *rowlock arches*.

BRICK ARCHES IN GENERAL

86. Arches should be laid up in cement mortar by careful and experienced workmen, or otherwise there is danger of the arches failing and letting down the weight imposed on them.

87. Definitions of Terms.—The following definitions of terms used in connection with arches are given. They may be readily understood by referring to Fig. 35.

Span.—The distance between the abutments, as shown at *a b*. The word *span* is also used to mean the material construction that spans, or covers, an opening or a gap.

Springer, or Skewback.—The stones or bricks that lie

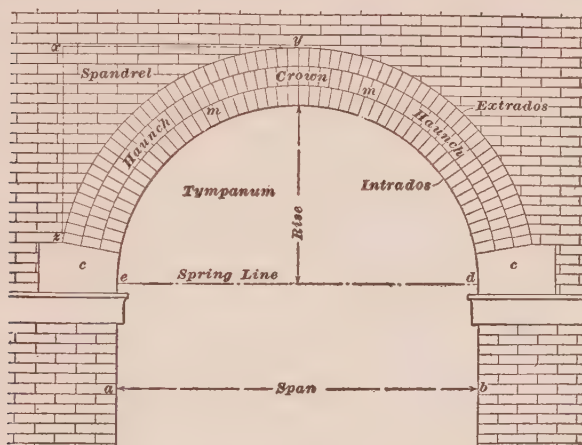


FIG. 35

immediately on the imposts, as at *c, c*, from which the arch proper springs.

Spring Line.—A line drawn through the points where the arch intersects the abutments, or where the vertical supports of the arch terminate and the curve begins, as shown at *e d*.

Intrados.—The lower concave surface of the arch, formed by the under sides of the bricks, although considered by some authorities to be the concave line at the edge of the under side of the bricks.

Soffit.—The lower surface of the arch, or the intrados.

Extrados.—The upper convex surface of the arch formed by the outer sides of the bricks in the arch; also, considered by some authorities as the convex line of the curve of the outside of the arch.

Rise.—The perpendicular distance from the spring line to the highest point of the intrados.

Arch Ring.—The arch itself, contained between the intrados and the extrados.

Crown.—The highest portion of the arch.

Haunches.—The portions of the arch included between the crown and the skewbacks.

Tympanum.—The space between the spring line and the intrados.

Spandrel.—The triangular wall space included between the extrados, a horizontal line drawn through the top of the

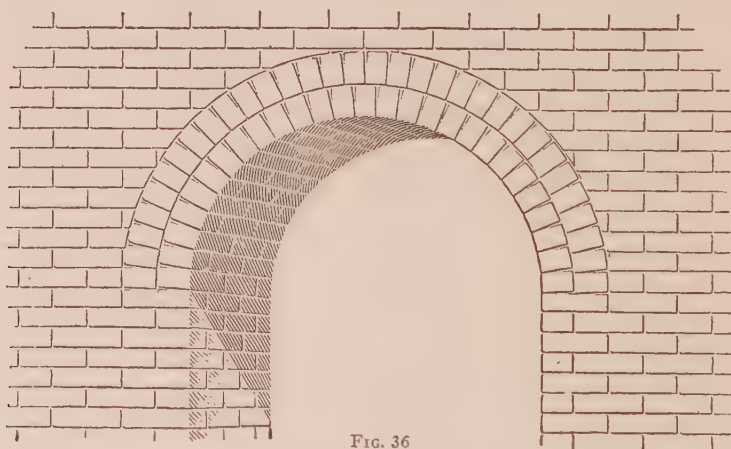


FIG. 36

extrados, and a vertical line drawn through the lower extremities of the extrados. This term is also applied to the space between two arches in a series of arches. The spandrel is shown at *z x y*.

Spandrel Filling.—The brickwork filling the spandrel.

Rowlock.—One of a series of arch courses, or rings, shown at *m, m*. There is no bond between these rings other than that afforded by the adhesion of the mortar.

88. Construction of Arches.—When semicircular arches are constructed of common bricks, the bricks are laid close together on the intrados, with wedge-shaped joints on the face of the arch; that is to say, the mortar joints are wider at the upper surface of the brick ring than at the lower surface, so that there is more mortar at the top of the joint than at the bottom.

Fig. 36 shows a semicircular arch consisting of two rings of rowlocks. These arch bricks are all laid as headers, and the long edges of the bricks show in the soffit of the arch. The increase of the thickness of the mortar in the joints is shown in the illustration.

89. Arches made of common brick are generally rowlock arches, and the difference in thickness of the joint in a distance of the width of one brick is not objectionable. An arch formed of bricks set with the length in the direction of the radius would require a decidedly greater thickness of joint toward the extrados than at the intrados. It is sometimes desired to use brick in this manner in connection with rowlocks in order to form a bond in the arch. In such cases it is necessary to have the bricks made to a radius, or wedge-shaped. Such bricks are called *gauged* or *shaped* bricks.

90. Gauged Bricks.—Fig. 37 shows a semicircular arch constructed of *gauged*, or *shaped*, bricks. The gauging, or shaping, may be accomplished by laying out the arch ring on a floor, and cutting, rubbing, or grinding the bricks to a certain gauge, or pattern, so that each brick will fit exactly in the place chosen for it; and all the mortar or radial joints will be of the same thickness throughout. This process is, however, expensive, and where there are many arches the brick should be molded in the required shape when manufactured.

In the example shown in the illustration, the space under the arch is filled by a brick wall supported on a bluestone lintel. This allows the bronze doors underneath to be made square on top.

As seen by the illustration, the extrados of the arch is stepped into horizontal steps. This is done so that the bricks



FIG. 37

in the wall will not have to be cut down to a knife edge in order to make them fit the work.

When the *reveal*, or space between a window or door frame and the outside of the wall, is only 4 inches, gauged-brick arches do not usually have any bond in the body of the wall except where metal ties are used; therefore, the bricks in the arch should be laid with great care and accuracy.

The class of work shown in the illustration is not often done in common brick, but is sometimes required in that material. The illustration shows the forms of bricks that will be required in such cases.

CHASES AND FLUES

91. Vertical grooves called *chases* and *flues* are frequently built in brick walls to receive plumbing, gas or heat

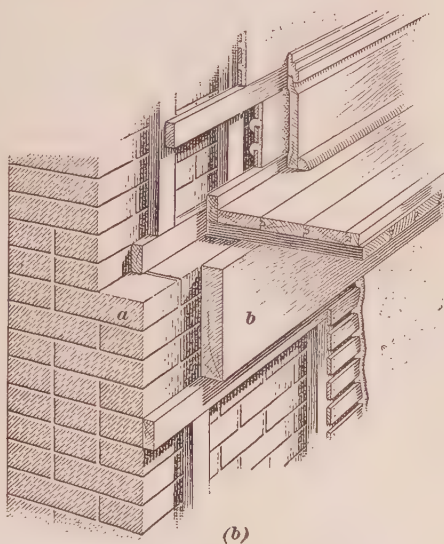
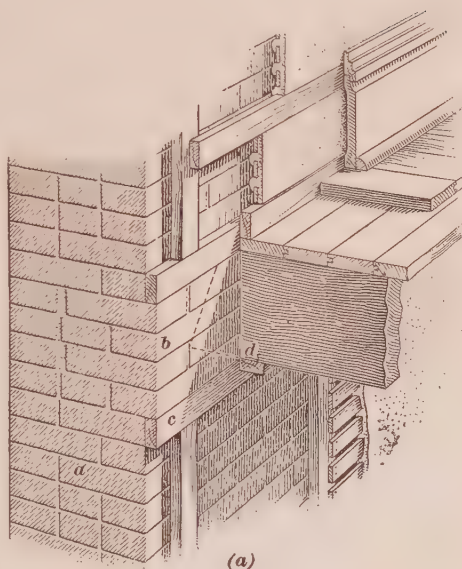


FIG. 38

pipes, etc. The building laws in some cities limit the number and size of chases that may be used in brick walls. For instance, the ordinances in force in New York City require that pipe chases shall not extend into any wall for more than one-third of its thickness and shall be not more than 4 feet in length measured horizontally. In the same ordinances, the areas of chases are counted in the areas of openings.

92. Fire-Stops.—Brickwork may be used to advantage as **fire-stops** to prevent the passage of flames from one floor to another back of the plastering. Brick walls are generally furred 1 inch, and this space, if continuous from floor to floor, permits the rapid spread of flames through the building.

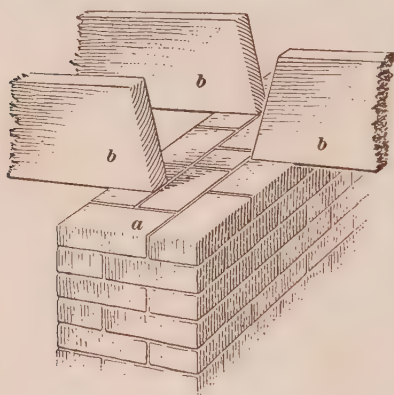


FIG. 39

Fig. 38 indicates a method of corbeling out the wall at the floor joists so as to close entirely the space between the wall and the plaster. At *a* in (a) is shown a wall of uniform thickness with the brick corbeled out at *b* for a fire-stop. A furring strip *c* makes a close joint with the cross-furring strip *d*. In (b) the brickwork sets back 4 inches, as the wall decreases in thickness at that point, as

at *a*, and *b* is a joist parallel to the wall. The wall should be carried up the full thickness to the top of the joists, and this will close all passages from floor to floor back of the plastering.

Where fire or party walls occur, the joists or beams should not be placed directly opposite each other, but should be staggered, as shown in Fig. 39. For adequate protection not less than 6 inches of brickwork should separate the ends of wooden joists. In Fig. 39 *a* represents a 12-inch wall supporting 2-inch joists on 16-inch centers. The joists *b* bear 4 inches on the wall and their ends are separated about $7\frac{1}{2}$ inches. With 3-inch joists similarly placed the ends of the

joists would be separated about $6\frac{1}{2}$ inches. Particular care should be taken to fill all joints in the brickwork with mortar, as unless this is done fire will find its way through from the end of one joist to the end of the other. In some cases it is difficult to secure 6 inches of brickwork between the ends of the joists, and in some cases steel beams may be used to secure the proper fire protection.

BACKING UP

93. As has been stated, common brickwork is frequently used in *backing up* stonework, terra cotta, and face brick. When this work is to be done, the stonework and terra cotta should be designed so that the heights of the courses shall be equal to the height of a definite number of brick courses, in order that the anchors or metal ties can extend back into the wall properly. For instance, with a customary size of brick, one course is counted as measuring $2\frac{1}{2}$ inches. The stone or terra cotta should be laid out in courses that are multiples of $2\frac{1}{2}$ inches in height. For instance, stone or terra-cotta courses should be made $7\frac{1}{2}$, 10, $12\frac{1}{2}$, 15, or $17\frac{1}{2}$ inches in height.

When a wall is faced with face bricks of other size than the common bricks used for backing, if the joints of the face brick are kept fine and those of the common brick thick, or vice versa, the courses will work out to the same height and permit of easy bonding every five to seven courses. As some Building Codes require frequent bonds, their provisions should be ascertained and bricks selected accordingly.

The same precaution should be taken in designing stone quoins, such as are used at corners of walls. The quoins should be designed to be a certain number of courses in height so that the bed joints of the stone will coincide with the joints on the brickwork.

EFFLORESCENCE

94. Very often, on buildings of stone or brick, more particularly the latter, white stains will appear on the surface of the walls after a few days of wet weather. These stains are

called **efflorescence**, and are due to certain soluble substances in the brick or mortar, or both. Carbonate of soda appears most frequently on new walls, and is due to the action of the lime in the mortar upon the silicate of soda in the bricks. Silicate of soda seldom occurs in bricks unless a salt clay is used in making the bricks. Sulphate of magnesia is formed when the clay contains pyrites, or when sulphurous coal is used for burning.

Water may reach the interior of the wall through absorption by the brick, through cracks and unfilled joints in the brickwork, through joints in the upper surfaces of copings or projecting courses, or from leaking or overflowing gutters and leader pipes back of the wall. When once the surface of the wall is penetrated, the moisture follows the joints and percolates to lower levels and to the outside surfaces, finally depositing the soluble substances by evaporation as stains or efflorescence.

Efflorescence may be prevented by the selection of impervious brick free from soluble materials, by filling all joints with mortar, by providing the upper surfaces of copings and projecting courses with overhanging coverings having drips, and by the proper design and maintenance of gutters and leader pipes.

Usually it is possible to remove efflorescence by washing the walls with a dilution of muriatic acid in 20 parts of water, which must be afterwards washed off with clean water. Several preservative coatings are designed to be applied to the walls after they are cleaned and dried. These preparations, by closing the pores in the brickwork, prevent the absorption of moisture. To be permanently effective, however, several coats must usually be applied, followed by additional coats at 2- or 3-year intervals.

HANGERS, ANCHORS, ETC.

95. The use of joist and girder hangers, etc. simplifies greatly the work of framing, both for house and mill construction. With these hangers and anchors, a good and firm bearing may be had in brick walls. The chief requisite of a good hanger is that it shall hold firmly to the wall and at the same

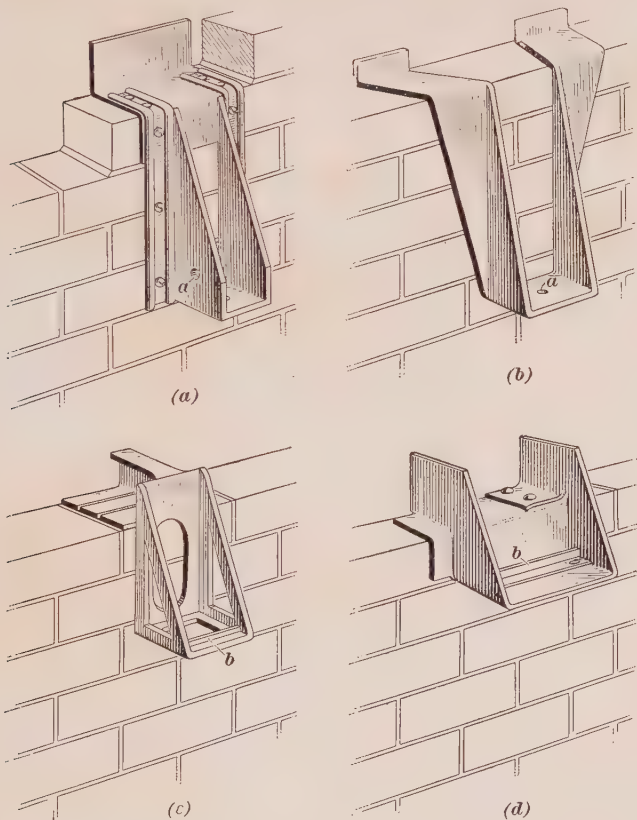


FIG. 40

time hold firmly to the joist. Fig. 40 illustrates four styles of hangers used to support joists and beams against brick walls. In none of these styles does the joist enter the wall, but rests in the socket; the top of the hanger being built into the wall.

In the hangers shown in (a) and (b), the joist is held in place by one or two spikes or lagscrews driven in through the hole *a* of the hanger and into the wood. In the hangers shown in (c) and (d), there is a ridge, or lug, *b* on the hanger. A notch is cut across the bottom of the joist and the ridge of

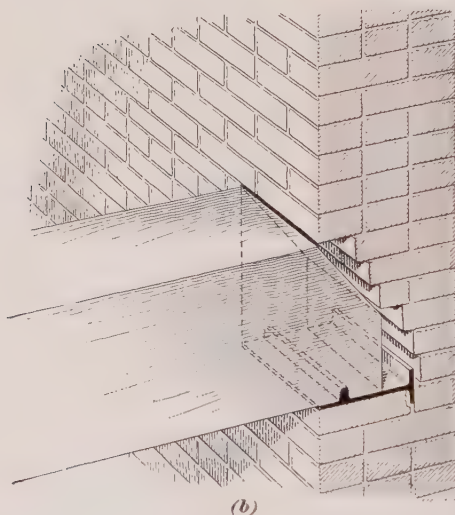
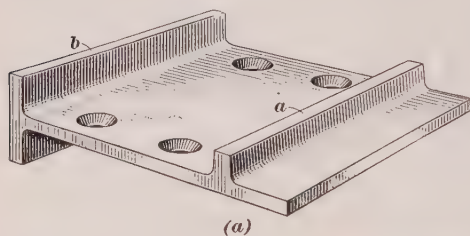


FIG. 41

metal fits into this notch. The hangers in (a), (b), and (d) are made of sheet steel stamped and bent into shape, while that shown in (c) is of cast steel. The hanger shown in (a) is known as a **Van Dorn** hanger; the one in (b) is a **Lane** hanger; and those in (c) and (d) are **Duplex** hangers. These hangers also act as anchors, as the end of the beam is held from moving horizontally either by spikes or by the lugs of the hangers. At the same time if the middle of the joist should fail and drop by overloading or by

fire, the end of the joist would easily fall from the hangers shown without injuring the wall.

96. In Fig. 41 is shown a wall plate that is used for wooden beams or girders that extend into the wall. In (a) is shown the bearing plate with the lug at *a* and the flange *b* which turns up and down into the wall. The beam is usually finished with

a bevel cut on the end, known as a **fire-cut**. This cut allows the beam to fall out of the wall without injury to the wall. The fire-cut is illustrated in (b).

97. In Fig. 42 are shown the four forms of iron anchors that are used for fastening beams in brick walls. The one

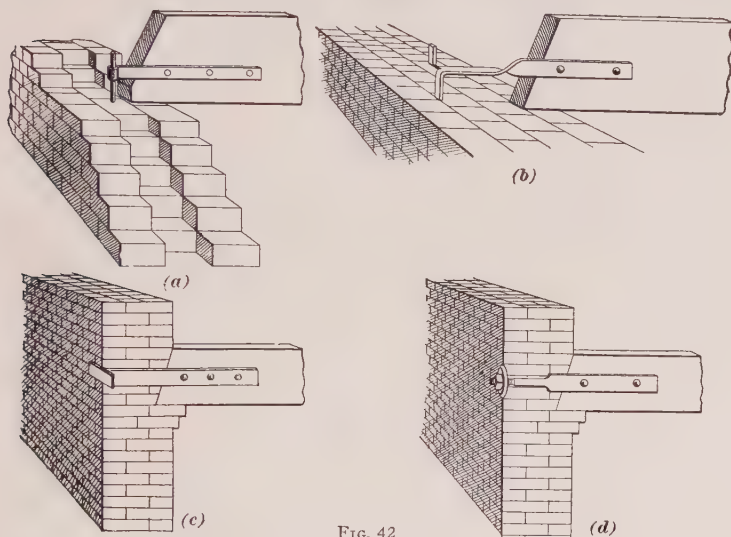


FIG. 42

shown in (a) is made of $\frac{1}{4}'' \times 1\frac{3}{4}''$ iron, about 2 feet long; the end built in the wall is made of a $9'' \times \frac{5}{8}''$ rod with the end of the anchor bent around it.

The anchor in (b) is made of $2'' \times \frac{3}{16}''$ iron, 2 feet long; the end that goes in the wall is cut as shown, and about 4 inches is

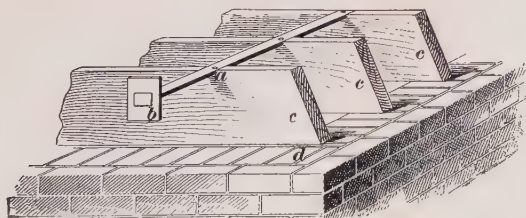


FIG. 43

turned at right angles to the anchor; the other end is twisted so that it can be nailed to the side of the joists.

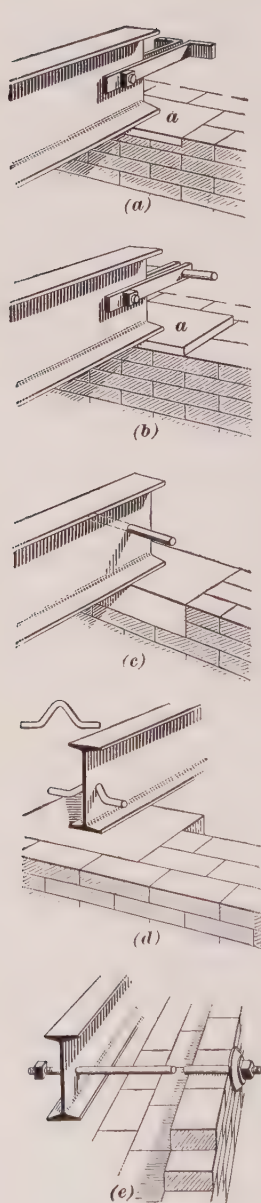


FIG. 44

An anchor that runs entirely through a wall is stronger than one that is simply embedded in a wall. On the other hand, the end of an anchor on the outside of a building makes an unsightly appearance. In warehouses and in back walls of buildings, however, when neat appearance is a secondary consideration, an anchor like that shown in (c) is used. It is made of $1\frac{3}{4}'' \times \frac{1}{4}''$ iron, 2 feet 6 inches long, and has a plate of $2'' \times 4'' \times \frac{1}{4}''$ iron forged on the outer end. This style of anchor may also be used in the middle of a wall in the same manner as those shown in (a) and (b).

In (d) is shown probably the strongest form of anchor. This style of anchor is made by flattening out a $\frac{3}{4}$ -inch bolt so as to make a $2'' \times \frac{1}{4}''$ portion to spike to the joist, and it is provided with a 5-inch cast-iron washer. A nut is placed on the outer side of the washer so that the anchor may be tightened up if necessary after the walls are built.

Anchors should always be spiked to the side of the joist or girder at or below the middle, as shown in the figure.

Fig. 43 shows the method of anchoring joists to walls where the joists and the walls run parallel. The anchor, let into the floor joists as shown at *a*, is provided with a washer *b*, and should be long enough to run over two or three joists, and 8 inches into the wall in order to give proper stiffness. The floor joists are shown at *c*, and the 12-inch brick wall at *d*.

98. Fig. 44 illustrates common forms of ties for anchoring I beams, channels, etc. to brick walls. Ordinary wall anchors are shown in (a), (b), (c), and (d), while in (e) is represented a tie-rod anchor running through the wall, to be used when the beam is run parallel to the wall.

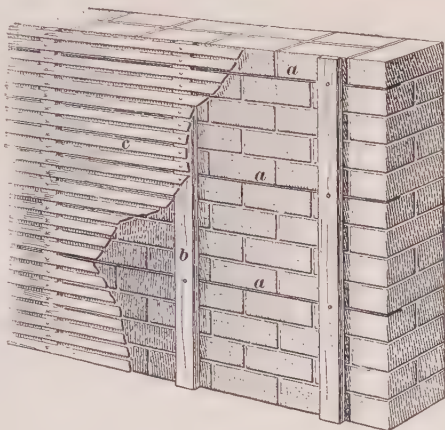


FIG. 45

Steel beams are generally supported on steel templets that are set in the wall. These templets, shown at *a* in (a) and (b), should be made large enough to distribute the load over a sufficient surface of brickwork so that the brickwork will not be crushed under the load.

99. Attaching Furring, Grounds, Etc. to Brick

Walls.—In most buildings it is necessary to attach wood or metal furrings, grounds, bucks, etc., to brickwork, and there are various methods used for this purpose.

Where the interior of the wall is to be furred with wood furring to receive lathing and plastering, common lath are laid between the bricks every few joints as shown at *a* in Fig. 45. They are held in place firmly by the brick and afford nailing for the furring. Wood should not be inserted in chimney walls and breasts, but metal furring and lath should be used, the furring being attached to wire loops

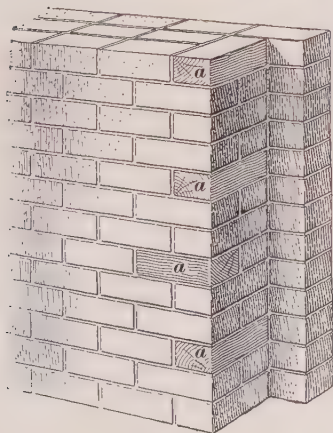


FIG. 46

inserted in chimney walls and breasts, but metal furring and lath should be used, the furring being attached to wire loops

or other devices built in the brickwork. Nails should never be driven into a chimney wall less than 8 inches thick, as they are liable to break out the mortar on the inside and render the chimney defective.

100. In special places, such as at a door jamb, it is necessary to provide specially good nailing, and **wood bricks** are

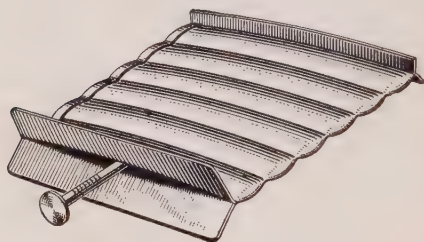


FIG. 47

built into the wall as shown at *a* in Fig. 46. These are blocks of wood of the same size as a brick and are built in the wall in the same manner as ordinary brick.

101. A patented device known as a wall plug

is shown in Fig. 47. This consists of a bent corrugated piece of metal that is built into the joints of the brickwork and into which a nail can be driven securely.

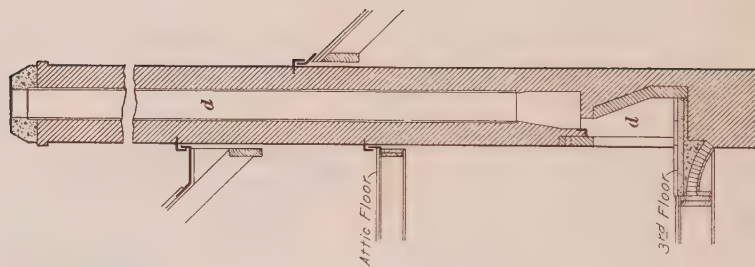
102. Devices for attaching work to brick walls, but which are not built in the walls, will be discussed elsewhere, as they do not properly come under the subject of brickwork.

CHIMNEYS AND FIREPLACES

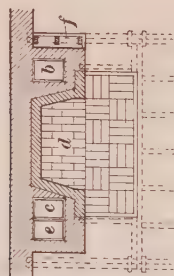
CHIMNEYS

103. Design.—The correct location, area, and height of chimneys should be carefully considered in designing a building. To make a chimney draw well, a separate flue should be provided extending from each fireplace, stove, or furnace to the top of the chimney. It is not considered good practice to use one flue for two or more of these features, although it is sometimes done with satisfactory results.

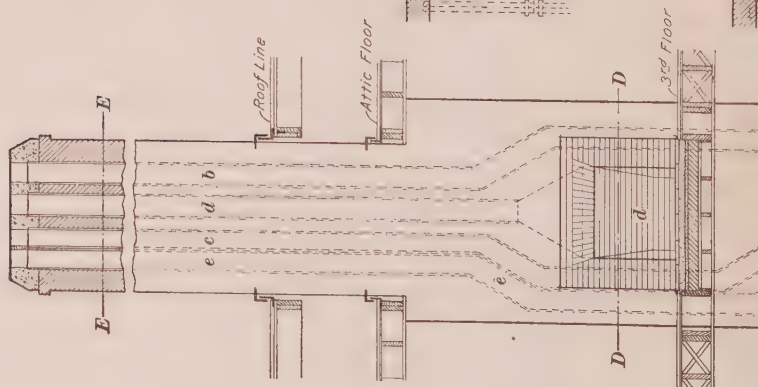
104. Construction of Chimneys.—Chimneys are generally constructed of brick and contain fireplaces, spaces for

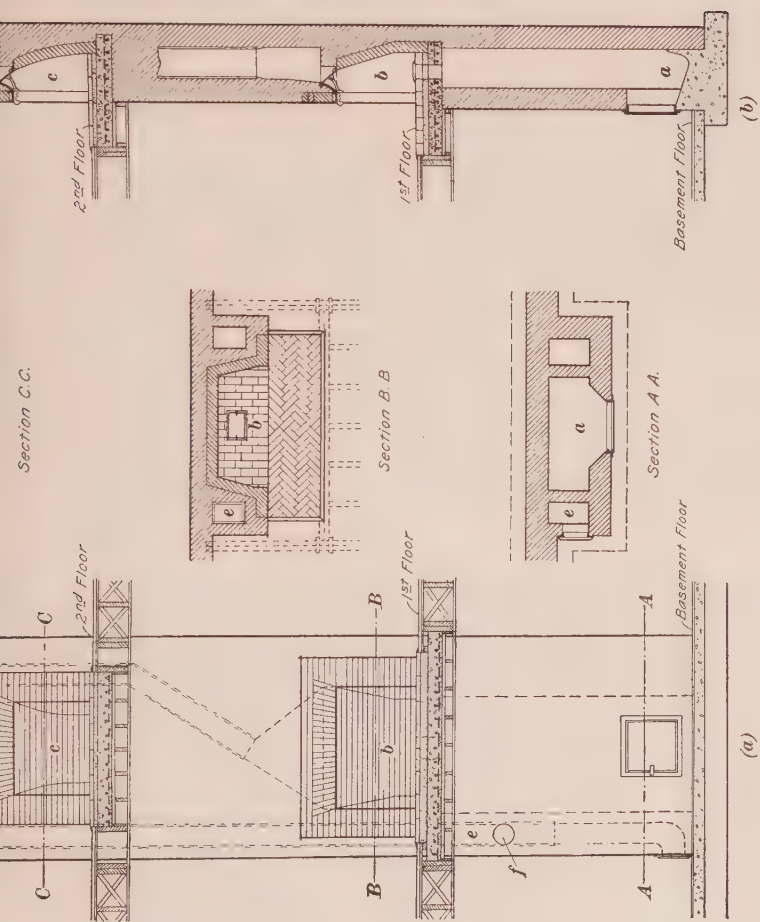


Section E.E.



Section D.D.





I L T 497-1843-2

(a)

FIG. 48

92413

ranges, ash-pits, flues, etc. These features are combined so as to form a compact and economical structure which is sometimes very complicated.

An example of the arrangement of parts in a chimney is shown in Fig. 48, which is a chimney built in with the side wall of a brick building. In (a) is shown a front elevation of the chimney; in (b), a section through the center lines of the fireplaces. Between these views are shown horizontal sections or plans of the chimney at each floor, in the cellar, and above the roof.

In the upper stories are shown the fireplaces *b*, *c*, and *d* and in the basement or cellar the ash-pit *a*. This ash-pit receives the ashes from the fireplace *b* through the ash door shown in the section (*b*). The ash-pit is provided with a cast-iron door through which the ashes are removed. A flue *e*, shown in dotted lines in (*a*), reaches from the basement floor to the top of the chimney. At the bottom of this flue, near the floor on the side of the chimney, is shown an iron door for cleaning out this flue. At *f* is an opening into the flue *e* designed to receive a smoke pipe from a heater or furnace. The flue *e* runs up past the fireplaces *b*, *c*, and *d* and is then bent toward the center of the chimney.

105. Flues.—The flues from the fireplaces are similarly shown by dotted lines extending from points above the tops of the fireplaces to the top of the chimney. The brick partitions between chimney flues are called **withes**. As shown, the flue from any fireplace must pass on the side of the fireplace above, but the flues are deflected above the last fireplace and brought together so as to make the chimney, where it extends above the roof, as compact as possible.

The bends in the flues should be as gradual as possible so as not to check the flow of smoke and gases up the flue. The double dotted lines indicate that the flues are lined with terracotta linings. These flue linings should be carefully cut to miter or fit together at the bends so as to form a smooth channel. Flues having slight bends are considered preferable to perfectly straight flues, as the bends prevent rain and sleet from

falling into the fireplace, and also tend to check the downward passage of currents of cold air. The smoke flues are sometimes formed in brickwork without linings, in which case the walls of the chimney should be 8 inches in thickness. The interiors of such flues should never be plastered, as the plastering is disintegrated by the heat and will fall off. When flue linings are used the chimney walls need be only 4 inches in thickness. Where linings are not used a 4-inch brick partition, or withe, should be built between the flues. The building codes of many cities require that all chimney flues be lined with fireproof material such as terra-cotta flue linings.

106. The advantages of using terra-cotta flue linings are several. In the first place, they are made in 24-inch lengths, which makes few joints. The inside surfaces of the linings are smooth and thus facilitate the flow of smoke and gases up the chimney. In unlined brick flues there is always a risk that the joints between the bricks may not be properly filled with mortar and that sparks will find their way through the crevices and start a fire in adjacent wooden parts of the building. When the flues are lined, however, this danger is reduced to a minimum.

107. Sizes of Flues.—The sizes of brick flues are generally made in accordance with the sizes of bricks used on the work. These flues are about 4, 8, 12, 16, and 20 inches in either direction. Terra-cotta flue linings are made in circular, square, or rectangular shapes. The square and rectangular flue linings are made to fit in with the brickwork.

108. In Table II is given a list of the customary sizes of terra-cotta flue linings. The dimensions of the square and rectangular flues are the outside dimensions. The thickness of the shell, which is from $\frac{3}{4}$ inch to 1 inch, is deducted in estimating the net area of the flue. The inside diameters of the circular pipes are given and the areas are easily calculated from them. While $4\frac{1}{2}$ -inch flue linings are listed in Table II, this dimension in a smoke flue is too small to be effective and should not be used except where unavoidable or in fireplaces where only gas is burned, which permits of the use of a small flue.

109. Proportions of Flues to Fireplaces.—A good proportion for flues for fireplaces in which wood or bituminous coal is to be burned is to make the sectional area of the flue equal to one-tenth of the area of the fireplace opening if the flue is rectangular, and one-twelfth, if the flue is circular. Thus, for a fireplace that is 30 inches wide by 30 inches high and whose area is 900 square inches, the flue area for the rectangular form of flue would be 90 square inches, which will

TABLE II

DIMENSIONS AND EFFECTIVE AREAS OF FLUE LININGS

Rectangular Flues		Circular Flues	
Outside Size Inches	Approximate Inside Area Square Inches	Inside Diameter Inches	Inside Area Square Inches
$4\frac{1}{2} \times 8\frac{1}{2}$	16.25	6	28.27
$4\frac{1}{2} \times 13$	27.50	7	38.48
$4\frac{1}{2} \times 18$	40.00	8	50.27
$8\frac{1}{2} \times 8\frac{1}{2}$	42.25	9	63.62
$8\frac{1}{2} \times 13$	71.50	10	78.54
$8\frac{1}{2} \times 18$	104.00	12	113.10
13×13	121.00	15	176.72
13×18	176.00	18	254.47
18×18	256.00	20	314.16
		24	452.39

require an 8"×12" brick flue. If flue linings are used, an $8\frac{1}{2}$ "×18" or a 13"×13" flue will be required. The area of a circular flue lining would be $\frac{1}{12} \times 900 = 75$ square inches. The nearest stock size of lining is 10 inches in diameter, which, having an area of 78.54 square inches, would be satisfactory.

If anthracite coal is to be burned, the flue area may be made one-fifteenth of the area of the fireplace opening for a rectangular flue, and one-eighteenth for the circular form. Thus, for a fireplace with an area of 900 square inches a rectangular

flue with an area of $\frac{1}{15} \times 900 = 60$ square inches will be required. According to Table II, an $8\frac{1}{2}'' \times 13''$ flue must be used for this area. A round flue of $\frac{1}{18} \times 900 = 50$ square inches, or 8 inches in diameter, will be needed.

110. Chimney Caps.—The portion of the chimney projecting above the roof should be laid up in strong cement mortar so as to prevent its disintegration, and should be covered with a protecting cap of stone or concrete. This cap may be pierced with holes to match the flues as shown in (a) in Fig. 49,

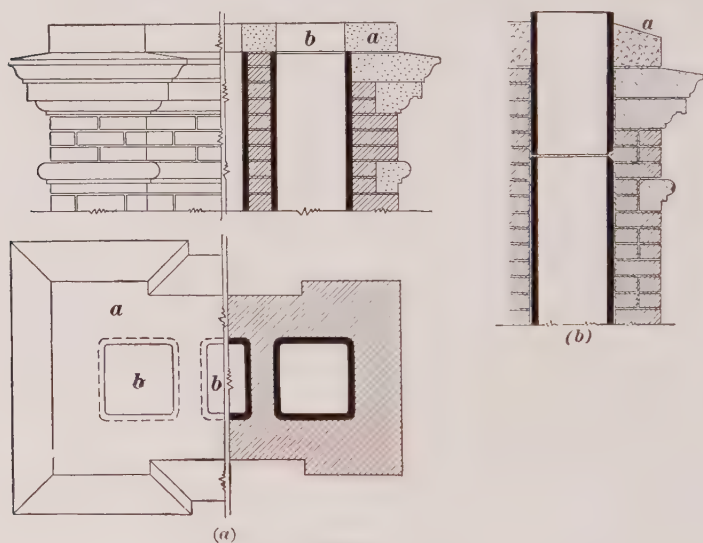


FIG. 49

in which *a* is the capstone of the chimney and *b* the holes cut through flush with the inner edge of the flue lining and covering the joints between the brickwork and the linings. This prevents water from entering the joints of the brickwork, which would soon cause disintegration of the mortar, loosening of the bricks, and discoloration on the exterior of the chimney.

Another method frequently followed is to project the flue lining above the masonry, as in (b), and to build on a concrete or cement cap, *a*. This prevents swirling air-currents, with perhaps accompanying snow flakes, from descending the flue.

It also tends to decrease the erosion under the cap due to water entering the exposed joints in the brickwork. Concrete, however, is more apt to deteriorate under heat, cold and moisture than stone, and thus is likely to prove less durable.

A chimney cap that is not perforated is shown at *a* in Fig. 50. This cap is supported at the four corners by small brick piers between which the smoke passes through the spaces *b*. Such a cap prevents rain and sleet from falling into the chimney.

111. Chimney Pots.—Instead of flat caps, **chimney pots** made of terra cotta are sometimes used. These pots form

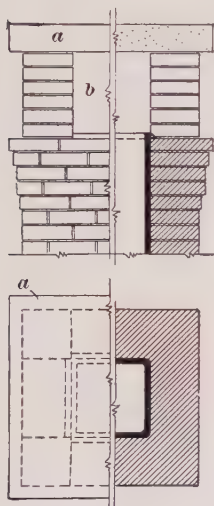


FIG. 50

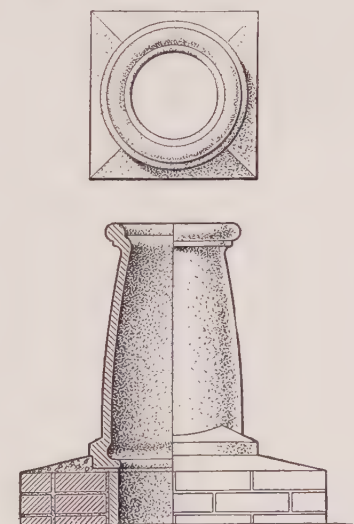


FIG. 51

a picturesque and ornamental finish to a chimney. They are made in many different forms, which are kept in stock by dealers. Examples of terra-cotta chimney pots are given in Figs. 51, 52, and 53 showing half exterior views and sections. The sections show the manner in which the pots are set, so as to cover the flue lining in the chimney. One pot is required for each flue. A strong cement mortar is used in setting the pots and is graded away from the pots to the outside of the chimney so as to form a wash. The design in Fig. 51 is a simple one

with graceful lines and is round or circular in plan. The design in Fig. 52 is more elaborate and is octagonal in plan.

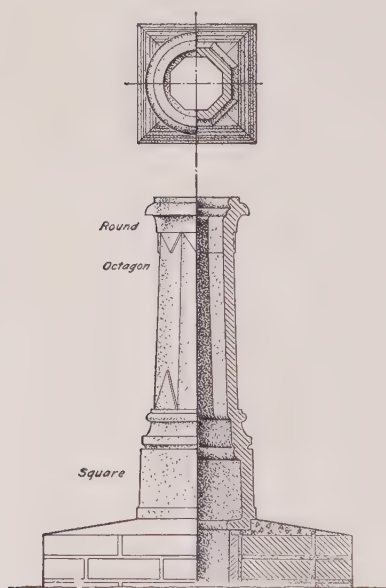


FIG. 52

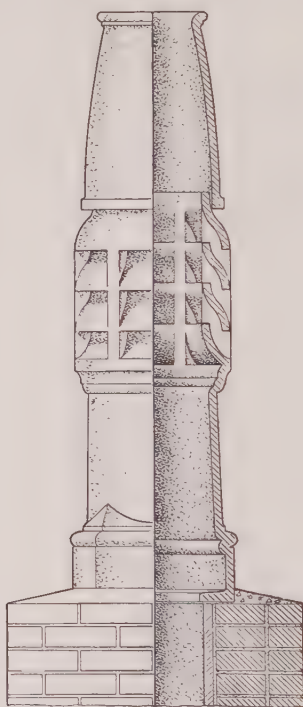


FIG. 53

Fig. 53 is a larger and more elaborate design than the others, with outlets for the smoke in the sides as well as the top.

FIREPLACES

112. Construction of Fireplaces.—The general construction of a fireplace is shown in Fig. 54. The projection of the chimney into the room to enclose the fireplace is called the *chimney breast*. The height of an ordinary fireplace opening should be about 2 feet 6 inches or 2 feet 8 inches above the finished floor, its depth from 16 inches to 24 inches, and its width from 2 feet to 5 feet. If the height of the opening is

made more than 2 feet 8 inches the flue should be made of such a size that the upward draft will be strong enough to prevent smoke coming out into the room.

While a good fireplace can be made that is rectangular in plan, it is better to slope the sides and back as shown in the

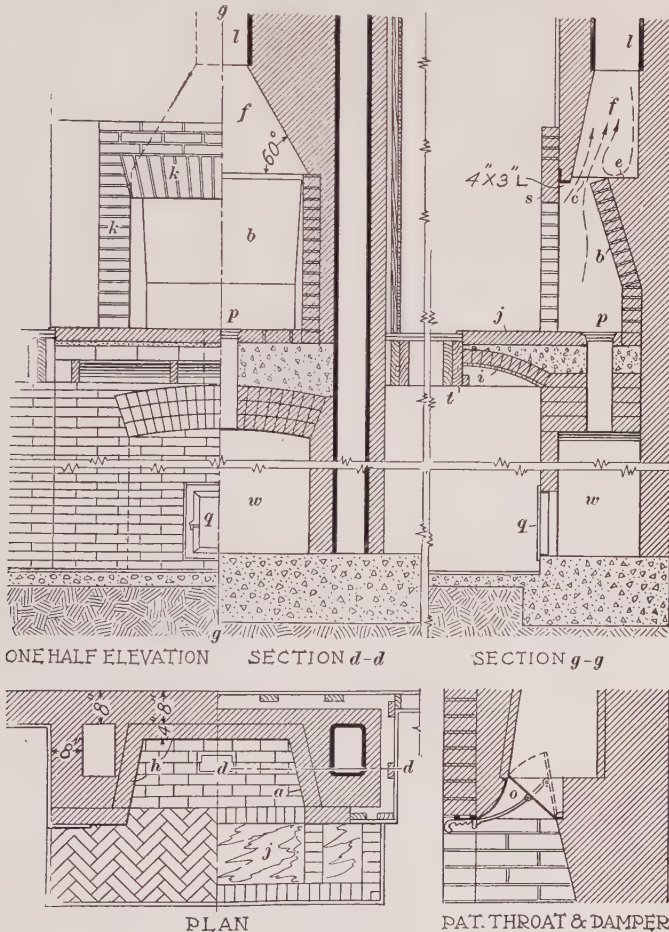


FIG. 54

figure, as these sloping surfaces throw the heat into the room. A slope of about 3 inches in 1 foot, as shown in the plan, is satisfactory.

The *back b* of the fireplace should slope forward and form the *throat c*, which should be from $2\frac{1}{2}$ inches to 4 inches in depth and the full width of the fireplace opening. The total area of the throat should be not less than the area of the flue lining. The throat should be, at least, 2 inches or 3 inches above the top of the opening of the fireplace as shown at *s* and as near the front of the fireplace as possible. Backs may also be curved, as illustrated in fireplace *c* in Fig. 48.

A *smoke shelf e*, Fig. 54, is an important feature. It prevents the air from rushing down the flue when a fire is started and forcing smoke into the room. The *smoke chamber f* is formed by drawing the brickwork together at an angle of 60° on the sides until it is reduced to the dimensions of the flue lining. The bricks should be clipped so as to present as smooth a surface as possible and not a series of offsets. The lining *l* is then started, being supported by the brickwork, as shown. The hearth shown at *j* is extended in front of the fireplace so as to catch embers that may fall out of the fire. It is supported on a trimmer arch *i*, consisting of a single rowlock arch about 20 inches wide springing from the chimney to the header *t*. This arch is laid upon a wooden center which is sometimes left in place, but is liable to be set on fire by a very hot fire on the hearth above. A better practice is to remove the centering of the trimmer arch and cover the space with metal furring and metal lath, to which the plastering may be applied. Upon the trimmer arch, the hearth is built up of cement or concrete and is finished in tile, marble, or brick. The hearth should extend at least 12 inches on each side of the fireplace opening. In Fig. 48 is shown another design for a hearth in fireplaces *b* and *c*. This design is built of reinforced concrete which is cast partly upon wooden forms and partly upon the masonry of the chimney. Iron rods are placed as shown and the concrete is poured so as to surround them. This construction forms a solid slab upon which the finish of the hearth is placed. This finish may consist of brick, tile, or cement.

113. Finish of Fireplaces.—The fireplace shown in Fig. 54 is lined with firebrick or good hard-burned brick. A

loose grate in which coal may be burned is sometimes placed in a brick opening. In some cases ornamental sheet-iron or cast-iron linings are placed in the fireplace as shown in Fig. 55.



FIG. 55

In this case a hard-burned common brick or else firebrick may be used in constructing the fireplace, as the lining will cover this work.

114. Patent Throats and Dampers.—As it is desirable at times to reduce the draft in a fireplace, a damper should be provided that will permit of partially or entirely closing the throat of the fireplace. There are several patent dampers on the market that are designed to be built in at the top of the

fireplace for this purpose. An example of such a damper is shown in Fig. 54, which shows by solid lines the position of the damper when closed and the position when open by dotted lines. Above this damper a patent throat is sometimes used and is made of concrete or of terra cotta similar to the flue linings. This throat forms the sloping smoke chamber that would otherwise be made in brickwork.

115. Ash Doors and Pits.—When possible, it is very desirable to have an ash door in the hearth under a grate through which ashes may be dropped into a suitable space in the cellar portion of the chimney. This arrangement is shown in Fig. 54, where the ash door is at *p* and the pit at *w*. A door *q* is provided at the bottom of the ash-pit through which the ashes may be removed from time to time. A similar arrangement is illustrated in Fig. 48.

ARCHITECTURAL TERRA COTTA

ADVANTAGES, USES, AND DESIGN

INTRODUCTION

1. Terra cotta such as is used for facing walls of buildings, forming cornices, columns, sills, and lintels over openings, etc., is technically known as *architectural terra cotta* to distinguish it from the form known as *structural terra cotta*, which is used in the construction of walls, partitions, floor arches, and enclosures for steel columns in fireproof buildings.

2. All terra cotta is made of clay or shale, which is ground with water in a mill, molded into shape, and then placed in a kiln and burned to a brick-like consistency. Architectural terra cotta is made of a better grade of clay than structural terra cotta and is so treated as to form a plastic mass that can be molded into forms of very intricate pattern. Great care is required in forming and handling the blocks, in finishing the surfaces, and in burning, to secure a product that will be free from defects and suitable for the purpose intended.

Although the process of manufacture has changed greatly in detail since terra cotta was first employed, about 600 B. C., the product as it comes from the kiln today is very much the same as that made by the ancients, who used this material for a variety of useful and ornamental purposes.

3. Terra cotta is extensively used for facings for exterior and interior walls of buildings, and for such purposes it is a durable, beautiful, and economical material.

Properly made terra cotta is fire-resistant, frost-proof, and weather-proof, in which characteristics it is superior to stone. It lends itself to a great variety of color effects and can be molded or ornamented with comparative ease to produce either plain or intricately ornamented work that will stand the wear and tear of centuries.

From the structural standpoint, terra cotta is a most desirable material to use on account of its durability and adaptability to many kinds of structures. It is equally adaptable to a building having masonry walls or one having a framework of steel or of reinforced concrete.

ADVANTAGES AND USES OF TERRA COTTA

4. Facings for Walls.—Terra cotta, when used as a facing for masonry walls, may be bedded in mortar and built into the wall in the same manner as stone or brick.

As a facing for a steel-frame or reinforced-concrete-frame structure, terra cotta is a desirable material, as the blocks may be designed and formed to fit the shape of the structural parts that support them. The blocks may be kept away from these parts a distance of from one to two inches to allow for irregularities in the structure, thus avoiding expensive cutting and fitting such as is often required when stone is used. In the forms of structures mentioned the terra cotta is usually attached to the supports by means of metal anchors, and the space back of the blocks is filled with masonry except in places where the terra cotta fits closely to the supports, in which cases the space may be filled with a cement grout.

5. An advantage that terra cotta has, when used as a facing for a reinforced-concrete building, is that the entire rough concrete structure can be built and completed on the inside before the terra cotta is applied. The terra cotta does not require to be bonded with the wall, piece by piece, as the wall progresses, but may be put in place afterwards and secured to the wall by means of metal anchors that have been previously built into

the wall. By this method, the terra cotta may be in the making at the factory while the building is being erected.

6. In addition to the employment of terra cotta for building fronts and for interior work, there is considerable demand for its use in cornices and balustrades to take the place of more expensive cut stone, copper, or perishable sheet metal, such as tin or galvanized iron.

7. Fire-Resisting Qualities.—Terra cotta is a good fire-resisting material, as it can stand the heat of a conflagration better than stone. It can therefore be used in office buildings and other structures where it is necessary to cover a steel frame with a material that will conceal and protect the steel and at the same time give a pleasing and permanent architectural finish to the structure.

8. Weather-Resisting Qualities.—As a weather-resisting material, architectural terra cotta is very superior. When properly glazed it is non-absorbent and is thus excellent for structures built in large towns and cities where smoke and dust are always in the atmosphere. Terra cotta can be so glazed that it is impervious to water, and buildings faced with it can be washed down whenever desired, and made to look as fresh as when new.

9. Lightness in Weight.—For special purposes where a saving in weight is necessary, terra cotta is especially useful, as in a dome where it is required that the structure shall be light in weight and at the same time durable and weather resisting.

10. For Ornamental Work.—Terra cotta as a material for ornamental work in buildings has several advantages over cut stone which make it especially desirable to use under some circumstances. One of these is that the sculptor who models any ornamental part of a building in terra cotta can be sure that his model will be accurately reproduced, because the process of casting terra cotta is a mechanical one by which the original model made by the sculptor is exactly copied in

the plaster mold and reproduced in the clay when pressed into the mold.

When stone is used, the sculptor makes a clay model from which a plaster cast is taken and this is copied by the stone carvers with more or less fidelity, according to their proficiency and the accuracy with which they can interpret the sculptor's original model. As a rule, sculptors themselves do not carve the stonework but are dependent for the excellence of the results upon the skill of the stone cutters employed by them.

11. Another advantage is that terra cotta can be glazed with any color desired, so that great variety in tint can be obtained; thus it is not dependent upon its natural color, like stonework, nor upon the color produced by the burning, as is the case with brickwork. The ability to glaze terra cotta with colors opens up a wide range of possibilities for the designer who appreciates the effectiveness of color in his designs. Color in terra cotta is not affected by time or weather. Though dimmed by dust or smoke, the material may be quickly restored to its original color by washing. Colored glazed terra cotta is called Faience or *polychrome* terra cotta, *polychrome* meaning many colored.

White, full-glazed terra cotta, described later, is especially useful for the fronts of buildings, for lining light-courts, or wherever it is desirable to reflect the light as much as possible.

12. Economy.—Terra cotta also has an advantage in economy, as it generally costs somewhat less than stone, and being lighter in weight requires less steel to support it.

Terra-cotta members having richness of detail, such as flutings, ornamental panels, belt-courses, elaborately modeled column capitals, or similar members, can be produced in duplicate at much less expense than in cut stone, each unit of which must be laboriously carved by hand. Even in the plain members that are often used as a facing, the blocks may be formed of practically one size and by the use of very few molds may be cast in great numbers, whereas in stone facings each piece requires to be cut and finished as a separate unit.

DESIGN OF TERRA COTTA

13. In designing buildings in which architectural terra cotta is to be used, the architect should have a good knowledge of the nature of terra cotta, as well as of some of the peculiar conditions that govern its manufacture. Architectural terra cotta should be designed in accordance with the characteristics of the material itself even when it is used to resemble some other material, such as cut stone.

CHARACTERISTICS AFFECTING DESIGN

14. The **characteristics** of terra cotta that affect its use and design are, first, that terra cotta is a burnt product that shrinks and warps somewhat in burning. This characteristic makes it difficult to use large pieces of terra cotta in plain-surface work, as irregularities in the surface will not look well in the front of a building. This defect is largely overcome by using the terra cotta in medium-sized blocks so that the deformities will be small and practically negligible.

A second characteristic is that the clay of which the terra cotta is made lends itself readily to modeling or ornamentation. The use of modeling or ornament over the surfaces of terra-cotta work serves to conceal deficiencies due to warping and shrinking, and terra-cotta work containing considerable ornamentation always looks better than plain work. This modeling can be done quite easily and, after a mold has been made for a piece of ornament, a great number of similar pieces can be cast in the same mold. Hence, the oftener an ornament is repeated on a surface the less will be the cost of the terra cotta per piece, as the repetition of the same pattern will be much cheaper than the use of a number of different patterns.

A third characteristic is that very elaborate, bold, and projecting ornament for special positions can be easily made in terra cotta. The modeler makes the desired form in clay and the model is cut up into suitable-sized pieces, dried, glazed, and baked.

A fourth characteristic of terra cotta is that it can be colored in any desired tints and thus a field for design in color is opened to the designer.

A fifth feature is that it can be finished so as to resemble other materials, especially cut stone.

Thus terra cotta lends itself readily to ornamental treatment either of a bold or a delicate nature, to elaborate or delicate color effects, and to texture design.

PLAIN SURFACES

15. Plain Blocks.—Where plain blocks are used to obtain certain features, such as ashlar faces, plain piers, mullions and panels, they should be medium in size and carefully finished before drying, and the joints should be rubbed so that the two adjoining blocks will fit together with perfect accuracy. A wall composed of plain blocks that are even slightly warped will have an uneven appearance, but if the blocks are paneled, molded, or ornamented in any way that tends to make the wall irregular in appearance, the eye will not notice any slight warping that may exist.

The effect of the shrinking and warping in plain blocks of terra cotta, due to the heat of baking, is shown in the flat portion of the wall above the second-story windows in Fig. 1. If, however, this part of the façade had been built with blocks about 10 in.×16 in. or 12 in.×20 in. in size, as has been done in the panel between the first- and second-story windows, these blocks could have been made so that the slight irregularities of the surfaces and joints would not be apparent. In contrast with this example is the wall similarly treated in Fig. 2, in which the blocks are made small and the imperfections are thus reduced to a negligible quantity. In addition to making the blocks small, the edges of the blocks are beveled. This treatment also tends to conceal any imperfections in the joints due to warping. This style of design is not recommended for large surfaces as it is adaptable only for designs using a tile or diaper effect.

Fig. 3 shows a building with a terra-cotta façade having



Fig. 1

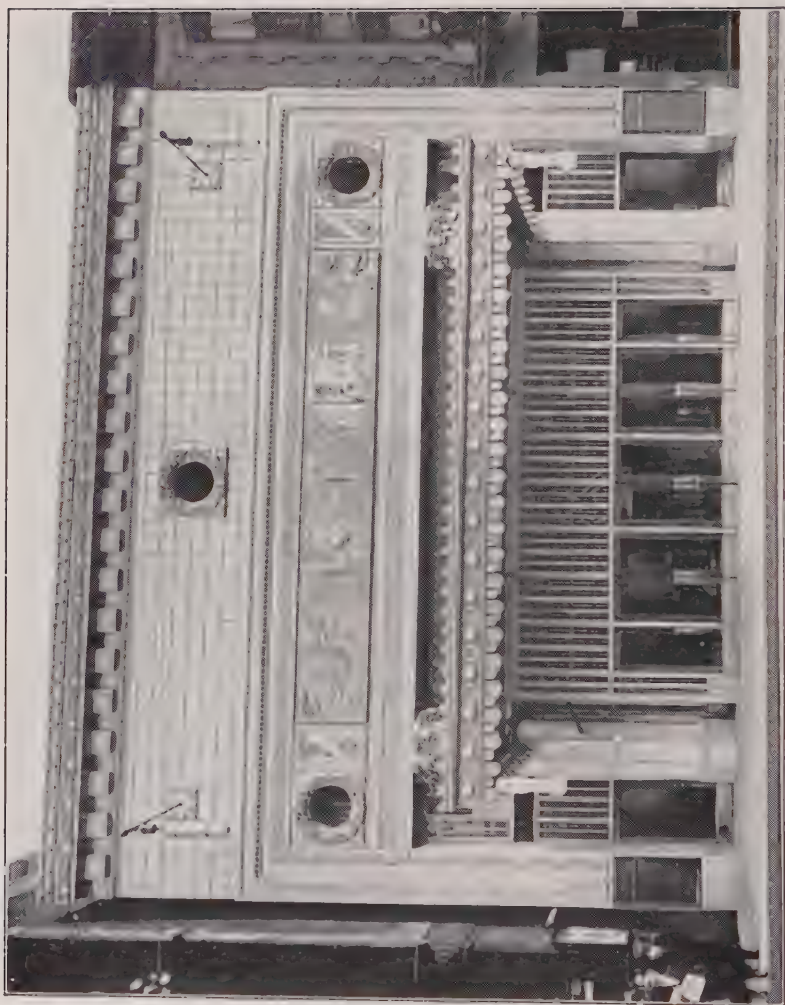


FIG. 2

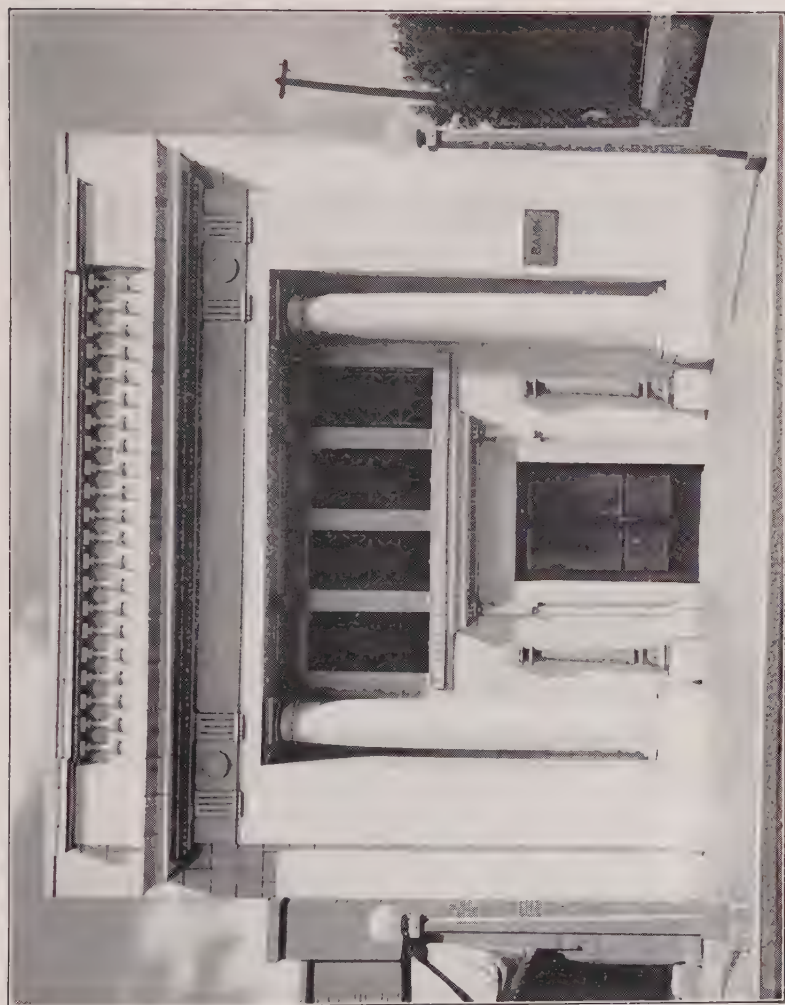


FIG. 3

plain stone-like surfaces which, while excellent, show slight irregularities in this case although they are excellent for terra-cotta work.

MODELING TERRA COTTA

16. Fig. 2 not only shows a proper treatment of terra cotta in plain blocks but illustrates the superior appearance of the terra cotta when richly decorated. It will be noted that there is a considerable repetition of blocks of the same pattern, which would be extremely costly if worked in stone. This example illustrates the possibilities of ornamentation in terra-cotta work in several ways. Shallow modeling, or *low relief* work, is shown in the borders and band courses. Bold modeling, or *high relief*, is illustrated in the wreaths around the circular windows and in the capitals of the polygonal piers. An excellent illustration of figure modeling is shown in the panel of dancing figures above the main entrance. This building is a very good example of the intelligent use of terra cotta.

17. Repetition of Ornament.—It is economical in the use of any plastic material, such as clay, to use the same ornament or motif repeatedly in the design, as this tends not only toward harmony of design, which might be too complicated otherwise, but also toward economy in manufacture. As every piece of terra cotta employed in a building must be formed in a mold, the fewer molds that are required the less will be the cost of the work. As the number of pieces needed in even a small structure often runs into the hundreds, and on larger buildings into the thousands, it can be readily seen that a large number of molds greatly increases the expense of manufacture. By repeating patterns, the same plaster mold can be used to cast from 25 to 40 blocks of the same design, which greatly reduces the cost of manufacture.

Designers should, therefore, see to it that they make their designs economical by using a repetition of patterns as much as possible. Thus, a simple running cornice in which each block is like its neighbor on either side, is less expensive to produce than a cornice composed of blocks of several different patterns.



FIG. 4



FIG. 5

Lintels and sills for windows, if all of the same pattern, can be produced with a minimum number of molds, but if the lintels on each story vary, or if the several parts of each lintel are different, the number of molds required will be very large.

18. Modeling in High Relief.—Terra cotta can be modeled in high relief ; that is, the ornament can be made so as to project boldly, as illustrated in Fig. 1, where an eagle in high relief is shown in the panel at the middle of the building above the windows. Bold modeling is also shown in the caps of the terra-cotta piers in Fig. 4, as well as in the ornament over the cornice of the door in Fig. 5. In fact, any projection that can be carved in stone can practically be made in terra cotta.

19. Limitations in Size of Blocks.—Stone can be used in large units, its size being determined only by the practicable size in which it can be quarried, worked in machines, shipped, and erected in place. Thus even huge columns of stone may be *monolithic*, or of a single piece of stone. Terra cotta, however, cannot economically be molded in very large units. There are several reasons for this. When undergoing the drying operation in the dry room, shrinkage in large pieces would be so much more than it is in small units that the blocks would tend to warp and crack. After drying, uniform burning in the kilns becomes very much more difficult with large blocks than with small ones and the warping is greatly increased because the heat does not attack all surfaces evenly. The handling and shipping of large blocks requires much more care than when smaller units are employed and there is much more waste from broken blocks. Hence the cost is greatly increased. It is not economical to use blocks greater in size than 27 in.×24 in. ×36 in. Blocks, especially thin facing or veneering blocks, are made much smaller than this size, as the smaller blocks are usually more economical to manufacture.

20. Practical Sizes of Blocks.—As a guide to the architect when designing terra-cotta work, Table I is given to show the most practical sizes of blocks to use for some of the principal parts of a building. In the table, the dimensions given in

the column headed *Depth into Wall* include not only the depth that the block extends into the wall but the amount it projects beyond the face of the wall. Thus, a cornice that extends 10 inches from the wall should extend about the same distance

TABLE I
PRACTICAL SIZES FOR TERRA-COTTA BLOCKS

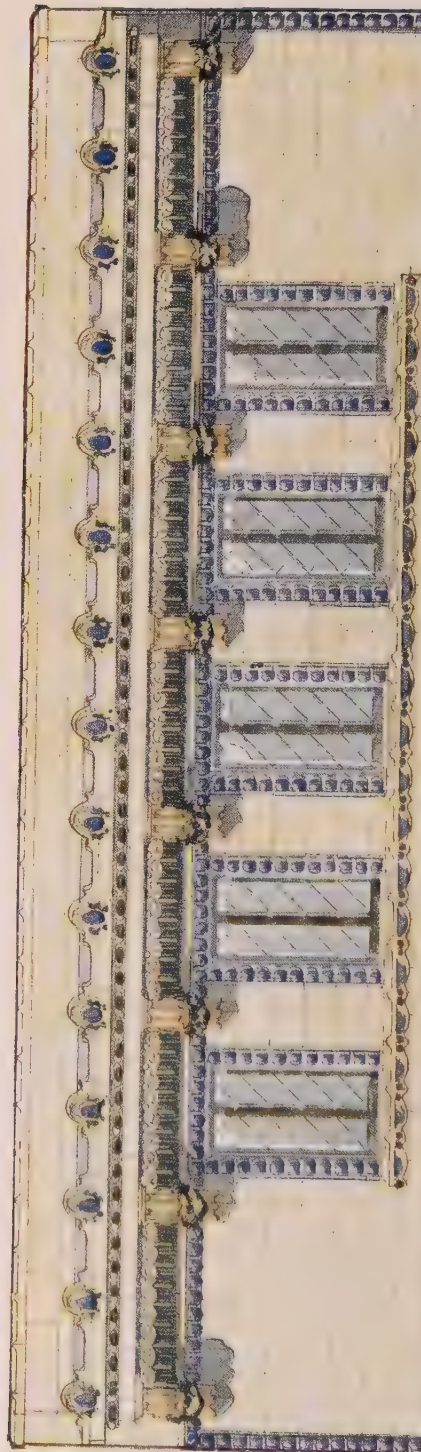
Members	Height Inches	Width Inches	Depth into Wall Inches
Cornices and string-courses.	10 to 24	18 to 24	12 to 24
Walls or panels.....	4 to 24	12 to 24	4 to 18
Sills and lintels.....	4 to 12	14 to 24	4 to 20
Jambs	14 to 24	4 to 12	4 to 12
Column drums.....	10 to 16		10 to 20 in Diameter
Columns, Segmental	10 to 16		10 to 24 Radius

into the wall, and its *Depth into Wall* dimension would be 20 inches. This applies generally, except when the terra cotta is supported by steel work attached to the frame of a building, when the blocks may extend only 4 inches into the wall.

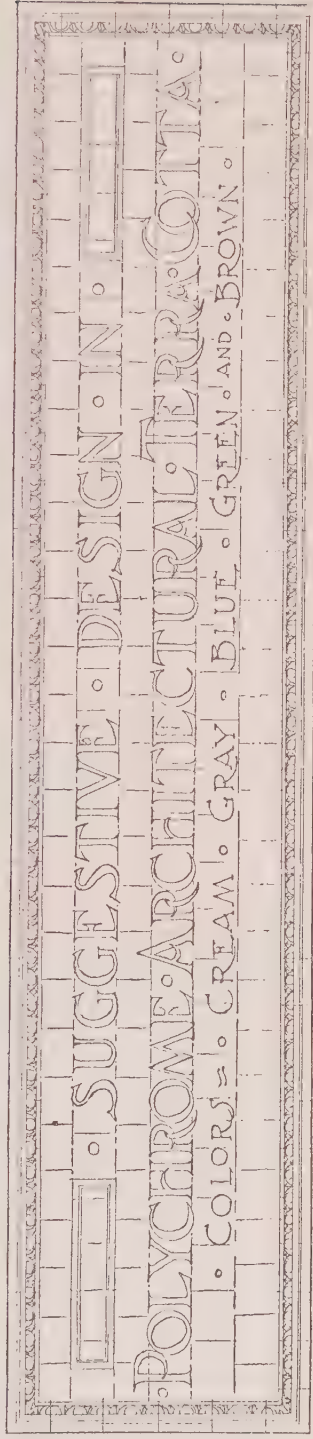
COLORING TERRA COTTA

21. Some of the most interesting designs in modern terra cotta are in colors, such as blues, greens, yellows, browns, and reds. Polychrome terra cotta in such designs is largely used for churches, office buildings, store fronts, theaters, and interior decorations; in fact, wherever the design itself is susceptible to the proper use of color. Usually the background of terra cotta is kept in one tone and the modeled portions of the design are in variegated colors. Hence, the latter stand out from the background, and many rich and beautiful effects are obtained.

In Fig. 6 is shown a good example of the use of polychrome terra cotta. In this case it is used for a theater front. The one-tone background consists of plain-surfaced pieces in a cream color and the modeled portions are in blue, green, and brown. The large panel immediately over the entrance to the building



HARMONY
ELECTRIC



is also formed of plain pieces, in a gray color. This panel is intended for an advertising sign which may be applied to its surface.

DESIGNING TO RESEMBLE OTHER MATERIALS

22. Architectural terra cotta is frequently designed to resemble other materials, such as stones of different kinds, and with various finishes. Granite, with its mottled or speckled coloring, limestone and sandstone with the various toolings of the surfaces, can be closely copied. The cost of the terra cotta is generally less than the cost of the stone. Terra cotta is frequently used in conjunction with stone on the same building, the walls and plain surfaces being finished in the stone, and the ornamental parts, such as cornices and the more richly decorated portions, being formed of terra cotta. When new, the difference in the materials can hardly be distinguished, but after a time the effect of the weather often causes a decided difference in the appearance. In using terra cotta to resemble another material the designer should never lose sight of the limitations of terra cotta.

23. Terra cotta that is designed to resemble some other material, such as granite or Bedford limestone, should have the forms of the blocks and the joints as like as possible to those generally employed for the material it is to be like, otherwise the effect it is desired to obtain may be lost.

To follow out this idea, quoins and rustications are sometimes used, arches with keystones may be employed over openings, and often pilasters and panels are used. In a façade intended to resemble cut stonework the greater number of vertical joints required by terra cotta, because of the small size of the blocks, tends to spoil the effect, but a little careful planning will make it possible to put many of the vertical joints in angles where they will not be noticeable.

24. In Fig. 5 is shown a building entrance made of terra cotta formed to resemble granite. This entrance is designed with both plain and ornamented parts. The lower members adjoining the doorway, which in the illustration show darker

than the remaining portions, are finished with a glossy surface called *full glaze* and the other portions are finished with a less glossy surface called *mat glaze*. These terms are defined more fully later in this Section. It will be noted in this illustration that the blocks of the upper part of the doorway are small in size, as indicated by the numerous joints, while no joints are visible in the lower members. This is due to the lower members being made in long narrow pieces and the joints being formed vertically in the design, where they are not noticeable. This gives this lower part the appearance of being formed of large pieces of granite, which adds very much to the attractiveness of the design.

25. In Fig. 3 is shown a building which has the entire front faced with terra cotta designed to obtain the effect of light-colored stone or white marble. The panel above the cornice, which forms the background for the balusters, is formed of small pieces. By locating the joints behind the balusters, the sizes of the blocks are not apparent, and the effect produced is that of the panel being formed of one large slab.

The columns of this building are formed of small pieces. If they were to be of stone, they would either be in large pieces or in a single piece for the entire shaft of the column. The entire front is formed of pieces of terra cotta that are, as nearly as possible, of the sizes and form that would be used were the material stone, thus carrying out the principle stated in Art. 23.

26. Figs 7, 8, and 9 all show the use of terra cotta in the construction and decoration of buildings of different types. In Fig. 7 is shown a handsome country residence in which terra cotta is used in place of stone for all the trimmings. The terra cotta is treated in a more ornamental manner than stone would be. The similarity of design in many of the parts is evident in the panels under the windows, over the entrance projection and over the porch. The square panels above the windows over the porch and over the entrance are of two patterns and are cast from two molds. The short pilasters around the top of the wall above the porch and the entrance are all of



FIG. 7



FIG. 8

the same pattern and made with one mold. Thus a very elaborate ornamentation is obtained by the use of three molds from which a great number of similar pieces have been made.



FIG. 9

27. An apartment building is shown in Fig. 8 which illustrates a profuse ornamentation made of terra cotta. The

basement walls are of plain terra cotta resembling stone, while the trimmings of the doors and windows are of molded and ornamented terra cotta used in the same manner as stone is used. The profuseness of the ornament is characteristic of terra cotta.

28. The building shown in Fig. 9 has the first-story walls faced with terra cotta designed like rusticated stonework. The balcony at the second-floor level has the design formed with plain blocks, and the brackets that support the balcony are very ornamental. The cornice and the members that surround the windows of the upper stories are all of a design that would be consistent were stone used for this purpose.

29. In all of these figures is shown the repeated use of similarly formed blocks both for plain and ornamented parts. Were the material stone, the ornamental parts of the design in many cases would not be attainable on account of the excessive cost in executing the designs in this material.

STOCK DESIGNS

30. Most of the terra cotta used for buildings is especially designed by the architect and is made to order. As the process of manufacture requires from six to eight weeks after the approval of the drawings and details, the architect often finds it desirable to use stock designs that can be obtained quickly and which often suffice for small structures. Most manufacturers keep a stock of molds for certain designs. The use of these stock molds reduces the cost of manufacture materially and also shortens the time required to make the terra cotta.

The designs that the manufacturers keep in stock necessarily consist of the more ordinary forms, for no manufacturer could afford to manufacture and carry a very extensive variety of patterns not knowing what the market demand might be.

For use in brick buildings, manufacturers also carry a line of stock designs for terra-cotta inserts, such as small ornamental blocks and small panels that can be readily inserted in face brickwork to produce an ornamental design.

Architects who contemplate using stock designs of terra cotta can obtain catalogs from manufacturers showing what patterns they carry in stock and giving the colors, finishes, and dimensions. The building in which it is proposed to use such patterns must, of course, be designed to fit the stock form of blocks, for the blocks cannot be cut and must be used in the size and shape in which they are manufactured.

An illustration of the use of stock patterns of terra cotta for a building front is shown in Fig. 1. The members which form each ornamental band or belt-course, also the panels of the pilasters, are small units of the same design, and plain pieces of terra cotta are used in various sizes to secure the required spaces for the ornamental parts. The coping is formed of both plain and ornamented pieces and is raised at intervals by means of special pieces to suit the requirements of the large ornaments that are placed over the second-story windows.

The panels over the first-story entrances, which contain the lettering, require to be made to order.

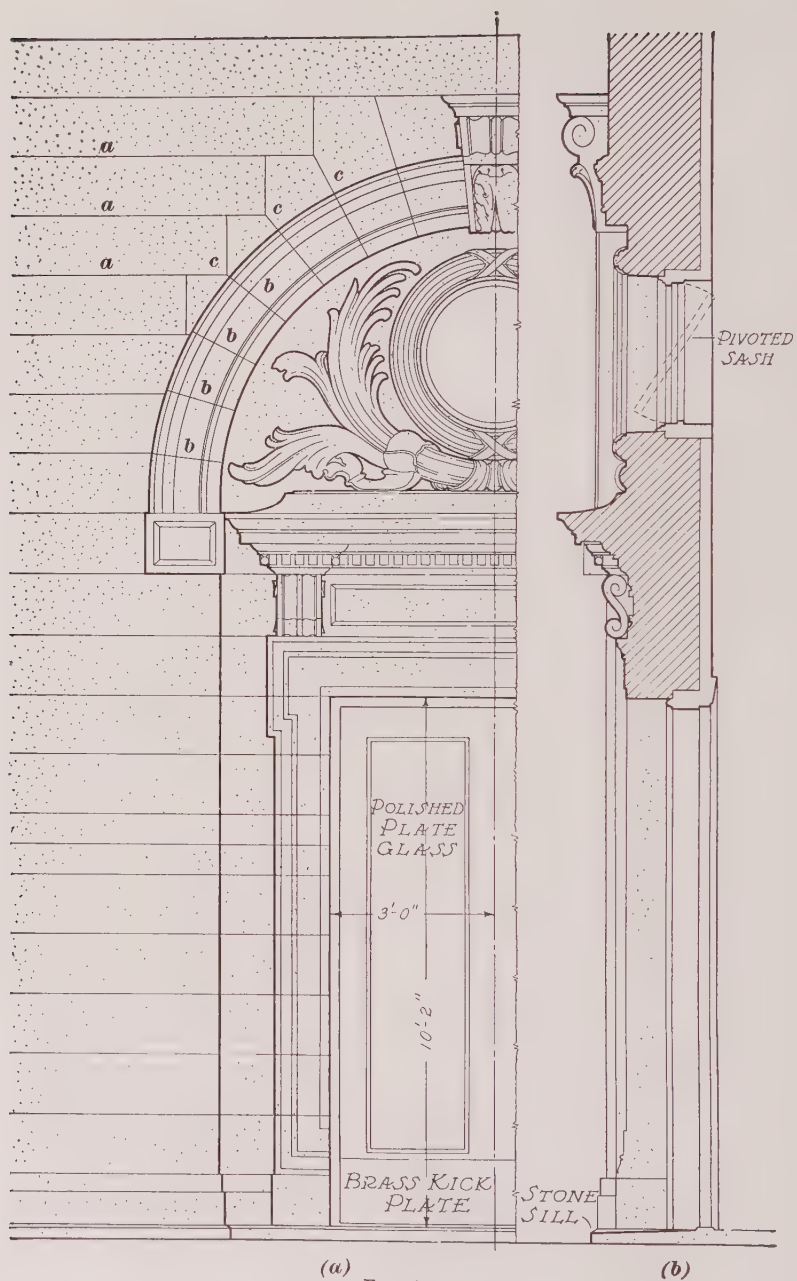
STRENGTH AND WEIGHT OF TERRA COTTA

31. Well-burned terra cotta will stand a compression test of 5,000 pounds per square inch, which is ample for any loads that are likely to be placed upon it.

The **weight** of hollow terra-cotta blocks, unfilled, is from 65 to 85 pounds per cubic foot. When filled with brick they weigh from 120 to 130 pounds per cubic foot, and when filled with concrete, from 130 to 140 pounds.

ARCHITECT'S DRAWINGS

32. The architect's drawings are made to show the design of the building which the architect has conceived and which he wishes to erect. They also are made to express the requirements of the design in such a manner that the contractor and the workmen may comprehend the intentions of the architect, provide the necessary materials and labor, and erect a structure of the form and design required.



(a) FIG. 10

(b)

The architect's original working drawings usually consist of plans, elevations, and sections, drawn to a scale of $\frac{1}{4}$ inch or $\frac{1}{8}$ inch to the foot. These should clearly indicate the various materials that are to be used and the general form of construction. If terra cotta is to be used, the drawings should show the parts that are intended to be plain, those that are to be ornamented, and the general supports on which the terra cotta is to rest. These drawings will be sufficient for the manufacturer to bid from.

After the contract for the terra cotta has been awarded, the architect should prepare large-scale drawings that will show fully the forms of the terra-cotta parts and will give suggestions as to the jointing. He may if he desires prepare full-size details that will show the contour of all moldings, as well as the nature of the ornamental parts. These drawings are then given to the manufacturer to follow when making his shop drawings. It is customary, however, for the architect to require the terra cotta manufacturer to make the full sizes in which case they are drawn to shrinkage scale.

33. Example of an Architect's Drawing.—An example of an architect's drawing for an entrance and wall finished in terra cotta is shown in Fig. 10. Such a drawing is generally made to a scale of $\frac{3}{4}$ inch=1 foot. An elevation of part of the entrance is shown in (a) and a section through the entrance in (b). At *a* in (a) are shown the architect's suggestions for the horizontal jointing of the wall blocks; at *b*, the jointing for the arch over the entrance; and at *c*, the jointing for the terra cotta in the wall where it intersects with the arch. The jointing of the ornamental panel over the entrance is not shown in this drawing, as it is left to the manufacturer to determine what forms of blocks he can cast that will conceal the joints as much as possible.

MANUFACTURER'S DRAWINGS

34. The architect's drawings are sent to the manufacturer of the terra cotta, who copies them and adds details of jointing and of anchoring the blocks to the constructional parts of the building. These drawings are then submitted to the architect for approval. The architect makes any changes and corrections on them that his judgment may dictate, marks them *Approved*, and returns them to the manufacturer. The manufacturer then proceeds to make further detail drawings which are drawn to what is called the *shrinkage scale* as will be described presently.

35. Example of a Manufacturer's Drawing.—In Fig. 11 is shown the manufacturer's drawing of the same entrance that was shown in Fig. 10. It will be noted that the horizontal joints of the plain wall, the radiating joints of the arch, and the joints *c* between the wall and the arch, as shown in Fig. 10 (*a*), have been retained. Vertical joints *d*, Fig. 11 (*a*), however, have been added to show the length of the wall blocks. The joints *e* and *f* are suggested for the ornament over the entrance. These joints are made to follow the form of the ornament as far as possible so that they may be partly concealed.

In Fig. 11 (*b*) is shown the contour of the terra-cotta blocks that occur in this section, the depths that these blocks set into the wall, and the manner in which they are secured or supported. All of the terra cotta over the doorway, also the masonry with which it is backed up, is supported by the steel members shown at *a* and *b*. Anchors *c* are used to tie the projecting blocks to the body of the wall. The blocks *d* are designed to form a self-sustaining arch, as shown at *g* in (*a*). To prevent any settlement of these blocks or the opening of the joints between them, they are usually anchored to the steel members by means of small suspension rods, shown at *f* in (*b*). The blocks *e* in (*b*) are likewise suspended from the steel member *a*. The diagonal lines show the backing which consists of brickwork.

In addition to the general dimensions, the manufacturer's drawings usually indicate the sizes of the blocks, as in Fig. 11. When these scale drawings have been approved by the architect, the manufacturer proceeds to lay out the details of the various blocks at the *shrinkage* scale, which is a scale that makes allowance for the shrinkage that invariably occurs when burning the blocks.

36. Shrinkage of Terra Cotta.—Since terra cotta shrinks in manufacture about 1 inch per foot, the full-size shop drawings are drawn larger than the required size of the completed blocks. Thus, when it is desired to make a block

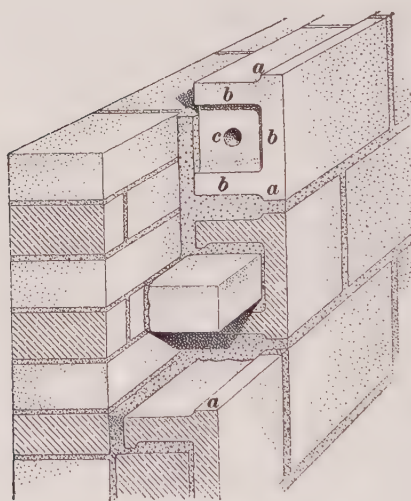


FIG. 12

12 inches long, the shop drawings show it 13 inches long. The plaster model and resulting plaster cast will be 13 instead of 12 inches long and the pressed-clay block will be 13 instead of 12 inches long. After the block has been dried and burned, however, it will be found to have shrunk to about 12 inches, or the size required.

Shrinkage can be estimated quite accurately, but it sometimes varies as much as $\frac{1}{8}$ to $\frac{1}{4}$ inch per

foot. Thus, a block estimated to shrink to an even 12 inches might prove to be when burned, $\frac{1}{4}$ to $\frac{1}{8}$ of an inch longer or shorter when it comes from the kiln. For this reason terra-cotta blocks are cast with a lug at each edge, which can be cut or rubbed down by machinery to make the block the exact size required.

The form of lug that is usually cast on the upper and the lower edges of the blocks is shown at *a* in Fig. 12. At the

ends of the blocks a similar form of lug is cast, as shown at *b*, and this projects beyond the face of the shell of the block *c*.

Variation in shrinkage is affected by the moisture or the stiffness of the clay when pressed into the mold, and by the dryness of the plaster mold in which the clay is pressed, since a dry mold will absorb more moisture from the clay than a moist mold. It is also modified by the exactness with which the clay ingredients are mixed, by the atmospheric conditions while the block is drying, and by the varying degrees of heat in different parts of the same kiln.

37. Design of Steel Supports, Anchors, Etc.—All the loose steel and iron necessary to attach, or anchor, the terra cotta to the building proper, must be designed by the terra-cotta manufacturer and shown on the drawings. He should also provide a schedule, or list, of all this iron and steel with his final drawings. Sometimes the contract requires that the terra-cotta manufacturer provide all this steel work, but as a rule the steel contractor provides it according to the schedule and drawings prepared by the terra-cotta manufacturer.

38. Final Approval of Manufacturer's Drawings. When the manufacturer's shop drawings are completed, they should be carefully reviewed by the architect to see that the designs conform in every way with his details from which the shop drawings were made. These shop drawings should show the full sizes of all moldings, the general construction of the terra cotta, and the proposed methods of anchoring the blocks to the building. The jointing also should be indicated.

It may be necessary for the shop drawings to be changed a number of times before they meet with the approval of the architect in all particulars. He should carefully review the final drawings and approve them before they are handed back to the manufacturers.

MODELING

39. When the architect has approved the drawings and has marked them accordingly, the work of modeling the various blocks is then begun. The plain work in which no molding or ornament appears is given to the average workman. Those parts of the work that consist of ornamented moldings, panels, cornices, brackets, and sculptural details are given to modelers of ability, whose duty it is to interpret the drawings in an artistic manner. Large manufacturers of terra cotta appreciate the importance of good models and usually employ only the most skilful men for this branch of the work. The results are that terra-cotta work can be used where fine artistic work is required and that this material is not considered as a mere substitute for stone, but as a material capable of the finest artistic expression when used in accordance with its peculiar characteristics.

40. Models.—Models are made for all ornamental pieces of terra cotta. These models are made of plaster of Paris, which forms the background, and moldings and the ornament are modeled in clay on the plaster backing. They are always made according to the shrinkage scale, that is, each 13 inches represents 12 inches in the finished product. The models of large pieces of ornament, panels, etc. are made without joints. The joints are put in later after the model has been finished and is ready to be cut up into blocks of convenient size.

41. Inspection by the Architect.—When the models are completed according to the drawings, the architect is notified; and if it is not convenient for him to call at the works and inspect the models, photographs are taken, a rule being laid alongside of each model to show the size and scale, and these photographs sent to the architect for inspection and approval. When this method is followed, two copies of the photograph of each model are usually sent to the architect, who indicates the suggested corrections and changes on each copy, returning one copy to the manufacturer and retaining the other copy for

the purpose of comparison with a later photograph which is sent him after his suggestions have been incorporated in the model. If the later photograph indicates that the model is satisfactory, he notifies the manufacturer accordingly.

If the architect can visit the plant to inspect the models for the terra cotta, it will prove more satisfactory than to attempt to judge and approve the models from photographs, as he can better appreciate the form, size, and details of his design by seeing them executed at full size in clay. He can also suggest changes that he may wish to make and have these incorporated in the clay and thus secure the desired effect. This done, he can approve the model and work can progress without further delay.

42. Cutting Up the Model.—After the model has been approved, it is cut into pieces of the right size from which to make the molds. The manufacturer usually determines the form and size of blocks that he considers best adapted to the design and to secure the best results in the burning. The jointing is indicated on the model or on the photograph that is submitted to the architect for his approval. Thus, an ornamental panel that may be 8 or 10 feet in diameter and in a single piece when inspected by the architect, might afterwards be cut into pieces not greater than 18 by 24 inches in size. The finished terra cotta comprising this panel will be cast in small blocks and combined to form the completed panel, all joints being filled with mortar.

If the joints are to be inconspicuous, the fact should be made known to the manufacturer before the model is cut into pieces, so that the joints may be cut around the ornaments, or that other steps may be taken to prevent the joints from showing when the different panels are built up.

MOLDS

43. Plaster Molds.—To reproduce in terra cotta the design that has been formed in the model, it is necessary to make a plaster-of-Paris mold of the model and use it as a mold into which the plastic clay is placed.

The plaster-of-Paris mold requires to be strongly constructed to withstand the pressure of the moist clay. It is usually reinforced with $\frac{1}{4}$ -inch square steel rods and the sides are bound with steel strap irons.

After the clay block has been formed, it is allowed to remain in the mold a sufficient length of time to dry properly before being removed. When it is removed it has the same contour and ornament as the original clay or plaster model.

MANUFACTURE OF TERRA COTTA

MATERIALS

44. Architectural terra cotta is made in somewhat the same manner as hollow tile or brick; that is, it is a material molded in clay and afterwards burned in a kiln. The manufacture of architectural terra cotta, however, requires a much more refined process than the manufacture of brick or hollow tile, the method is also more complicated, and the product must be worked with a larger amount of skilled labor.

45. Clay.—Clay used for architectural terra cotta must be of a higher grade than that used for brick. Terra cotta that is to be glazed requires clay free from impurities that tend to fuse in the kiln, as this action will cause the glaze to pop, making unsightly stains, crazing, or fractures.

46. Shale.—Shale is very largely used for the manufacture of terra cotta. Clay and shale from different parts of the country acquire different colors when burnt in the kiln, some coming out with a light yellowish tint, some a deeper shade of

salmon, others light or dark buff, while some are a strong brick red.

As terra cotta is a material that may be artificially glazed, the finished color does not depend upon the natural color of the body that is secured by the burning.

47. Location of Plant.—A plant for the manufacture of terra cotta is rarely located close to the source of supply of the required clay, for usually it is more desirable to keep the factory near the supply of labor and ship the clay such distance as is necessary. Furthermore, the bank of clay sometimes runs out, or the clay changes in character to such an extent that it is not suitable for the quality of terra cotta desired.

48. Treatment of the Clay.—The clay is received at the factory and is allowed to weather, which causes it to crumble and pulverize. It is then mixed with about 30 per cent. of burned clay that has been ground fine. The mixture is then pulverized by special machinery, and afterwards mixed with water and treated in a pug mill until it becomes a smooth soft mass of material capable of being molded or cast. It can be kept in that state until required for use.

49. Manufacture of Blocks.—The prepared clay is taken to the pressing room, where it is pressed into the plaster-of-Paris molds and then artificially dried with hot air, a process that usually requires from 2 to 3 hours. By this time the material has dried and stiffened sufficiently so that the blocks can be taken from the molds and handled without injury.

The raw blocks are then finished; that is, the seams are removed and the ornament is cleaned out.

If the blocks are to be finished with a smooth glazed surface, they are troweled smooth, and in this process the pores of the clay become closed and the finished surfaces of the material are made smooth and firm to receive the glaze.

Next, the blocks are placed in dryers, where they are subjected to hot air. This expels all moisture from the blocks, gradually making them bone dry. This drying takes about 48 hours.

The blocks then go to the glazers, where the exterior, or visible, surfaces are coated with a color or glaze as desired. They are then ready for burning and are taken to the kiln and subjected to a heat of from 2,000 to 2,300 degrees F. The burning process usually lasts from 12 to 14 days.

All terra-cotta blocks are made hollow, and the outside shell, which is usually 1 inch thick, is stiffened with webs, which are also about 1 inch thick. The number, size, and thickness of the webs and the thickness of the shell are determined by the size of the blocks, large blocks requiring a thicker shell and more webs than small ones. The voids are placed about 6 inches on centers.

Webs and shells of blocks have holes cast in them to facilitate anchoring them to the wall or structure. These holes also facilitate the handling of the blocks, as it is possible to pass the fingers through the holes when carrying the blocks. At the same time holes make the blocks lighter in weight and furnish a better bond for the mortar, which can flow into them and form a key.

FINISHES AND COLORS

50. Owing to the fact that terra cotta is formed of plastic clay, any finish or texture of the surface may be obtained by treating the block when it is being formed. Like pottery and faience, the clay may also be tinted, and any color, combination or blend of colors may be secured when it is burned in a kiln.

51. Texture.—The texture of the material is obtained in three ways: (1) By reproducing the sample of the surface to be matched, by modeling it in clay in the face of the plaster model before it is molded. This method is used to reproduce picked, stippled, crandaled and bush-hammered surfaces; (2) tooled surfaces are cut in the mold by special tools; (3) smooth-, light-, and rough-drag surfaces are obtained with finishing tools after the blocks have been removed from the mold. These textures may imitate rough, smooth, tooled, or polished stonework. To produce imitation granite, limestone, or sandstone, the manufacturer uses for his model a block of

real stone and can produce an accurate imitation, either of polished or dull finish or of the texture given to the stone by means of tools or hand modeling.

52. Coating or Spotting of Terra Cotta.—In terra cotta the original mixture of clay has little influence on the final color, which is obtained by tints applied in the form of slips, or glazes. These glazes produce the plain colors such as are seen in polychrome terra cotta. The mottled finishes are obtained by spotting the surface or the slip with various colors to produce effects such as the mottled colors of granite or other stones of a spotted nature. Thus, by combining spotting and texture, endless variations are possible.

53. Glazing.—The final process of treating terra cotta before it is burned is known as *slipping* or *spraying*.

Terra-cotta plants usually maintain a laboratory where the various clays, colors, and glazes are experimented with. Mineral colors are used in coloring and glazing and these materials do not look the same after they are baked as when they are applied to the unburned block. The burning produces a chemical change in the colors. Hence when seeking new shades of color the chemist applies the coloring material to a small briquette of terra cotta, burns it, and notes the results. The formulas for all mixtures of color and glaze are carefully preserved, so that given colors can be reproduced at any time. When it is decided to use a certain color or glaze, the coloring materials are carefully weighed and mixed together in exact proportions with the greatest care according to the formula for that color. The colors are mixed with water and applied to the blocks before burning, by means of a spray from an air brush. With some glazes or where a full gloss is desired on the surface, it is sometimes necessary to put on an *under glaze* as a first coat, and apply the final glaze over this.

54. These glazes are used to furnish the colors required by the design and at the same time they make the surface of the terra cotta more or less impervious to water. There are four finishes that are usually specified by architects. These are

the *standard*, or *unglazed*, which is not wholly impervious to moisture; the *vitreous*, which is impervious to moisture; the *mat-glazed*, or *mat-enameled*, which is glazed, has a dull finish, and is impervious; and *full-glazed*, or *enameled*, which is impervious and has a glossy finish.

In addition to these standard finishes, terra cotta, as has been stated, can be treated in any desired shade or color, to form polychrome terra cotta. Different parts of the block may be treated with different colors. If not otherwise specified, most manufacturers base their estimates on the *standard color*, which is that of light Indiana limestone, and is unglazed.

55. In **standard** finish, the terra-cotta blocks, after drying and before burning, are covered with a coating of clay *slip*, applied with an air brush. This produces a dull finish which is not "glassy" and the terra cotta so treated is not impervious to moisture, but has about the texture of good hard burned face brick.

In the **vitreous** finish, the glaze, or slip, is prepared with more of a glass-like quality by the addition of suitable minerals. This is also put on with an air brush, and two coats may be necessary to obtain the color desired, the first coat being a slip of one color to fill the pores of the blocks and the second coat a glaze of the same or another tint, depending upon the effect desired.

The glaze used in the vitreous finish vitrifies when burned; consequently, terra cotta with this finish is impervious to moisture. This glaze is, however, very thin.

Mat-glazed, or **mat-enameled**, finish, as its name suggests, is a dull glazed finish in which the glaze employed is of a glass-like nature but the finished blocks are not glossy. The glaze is heavier than that used on semiglazed terra cotta. The surface of mat-glazed terra-cotta blocks is impervious, hence they are excellent for outside work where the weathering qualities of the blocks must be considered. Mat-glazed finish can be washed down as readily as full-glazed.

Full-glazed terra-cotta blocks, as their name implies, are coated with what is practically liquid glass, which when burn-

ing fuses and leaves a glossy finish excellent for its weathering qualities and because it can so readily be washed clean. This finish is, however, expensive and not frequently used.

FITTING AND NUMBERING THE BLOCKS

56. Fitting the Blocks.—After the terra-cotta blocks have been burned they are allowed to remain in the kiln until they cool. They are then taken to the storage shed and the pieces are laid out on a floor in the order in which they will appear in the finished building. The pieces are carefully fitted together to see that they are the exact size and shape called for by the shop drawings. Any pieces that are imperfect are sorted out and new pieces made to take their places.

When the blocks are laid out, every block in a string-course or cornice, lintel, or jamb is carefully placed to see that the length of the course is just right as shown on the plans. Thus, a cornice composed of many blocks of terra cotta is like one composed of cut stone, each piece of which must be carefully made from the architect's drawings so that when they are placed together and the proper allowance made for the mortar joints, the total length will meet the requirements of the drawings.

Some of the blocks may require to be cut down slightly, and to accomplish this result the lugs on either end, which are provided for this purpose, are cut with a chisel; or if the excess is very slight, as is usually the case, one or both ends of the blocks are rubbed down by machinery.

It is the usual practice to rub or cut down all adjoining edges of blocks whether any great excess of length has to be removed or not, as this treatment secures a true and square edge at the joints, consequently the lugs are formed sufficiently long to permit of this rubbing without cutting into the shell of the block.

To insure the proper inspection and jointing of the blocks by the manufacturer at the plant, however, the architect should incorporate in his specifications definite requirements regarding this work. This is desirable in order that imperfect pieces may

FIG. 13

be replaced as soon as possible instead of waiting for errors to be discovered at the building, when the work will be delayed while new pieces are being made.

57. Numbering the Blocks.—After the blocks have been fitted together at the factory, each piece is marked on the back with black paint. A diagram is then made which shows each block of terra cotta, and this is marked with letters and numbers to correspond with those placed on the blocks. This diagram is sent with the shipment of terra cotta to the building so that the workmen can readily assemble the blocks in precisely the same order in which they were fitted at the factory.

This assembling diagram, sometimes called the *setting plan*, usually consists of a blueprint of the manufacturer's scale drawing on which is shown every block and all the joints. Fig. 13 is an illustration of such a plan for the terra-cotta entrance shown in Fig. 11. The terra cotta of each story is usually indicated by a large capital letter, *A* representing the first story and *B* the second story, etc. Each special feature is represented by a smaller capital letter, that, in connection with the larger capital letter and a number, is used in marking each block.

Thus, the plain wall facing for the first-story wall is labeled *A*, as indicated in Fig. 13, and each block has a special number. The arch over the entrance is marked *A^D*. All the pieces of terra cotta forming this arch are marked *A^D* and a special number, as *A^D.1*, *A^D.2*, etc. This system of marking absolutely identifies each block and, having the setting plan and the number on each block, the contractor should have no uncertainty in picking out the blocks.

58. Another system of marking the setting plan and the blocks is illustrated in Fig. 14 which has some advantages in the way of simplicity. The different features of the building are lettered *A*, *B*, etc., but by this method all similar blocks have the same number. Thus, all the wall blocks are marked *A* and all the blocks shown marked *A 5* are of the same size and pattern, and all marked *A 4* are of the same size and pattern.

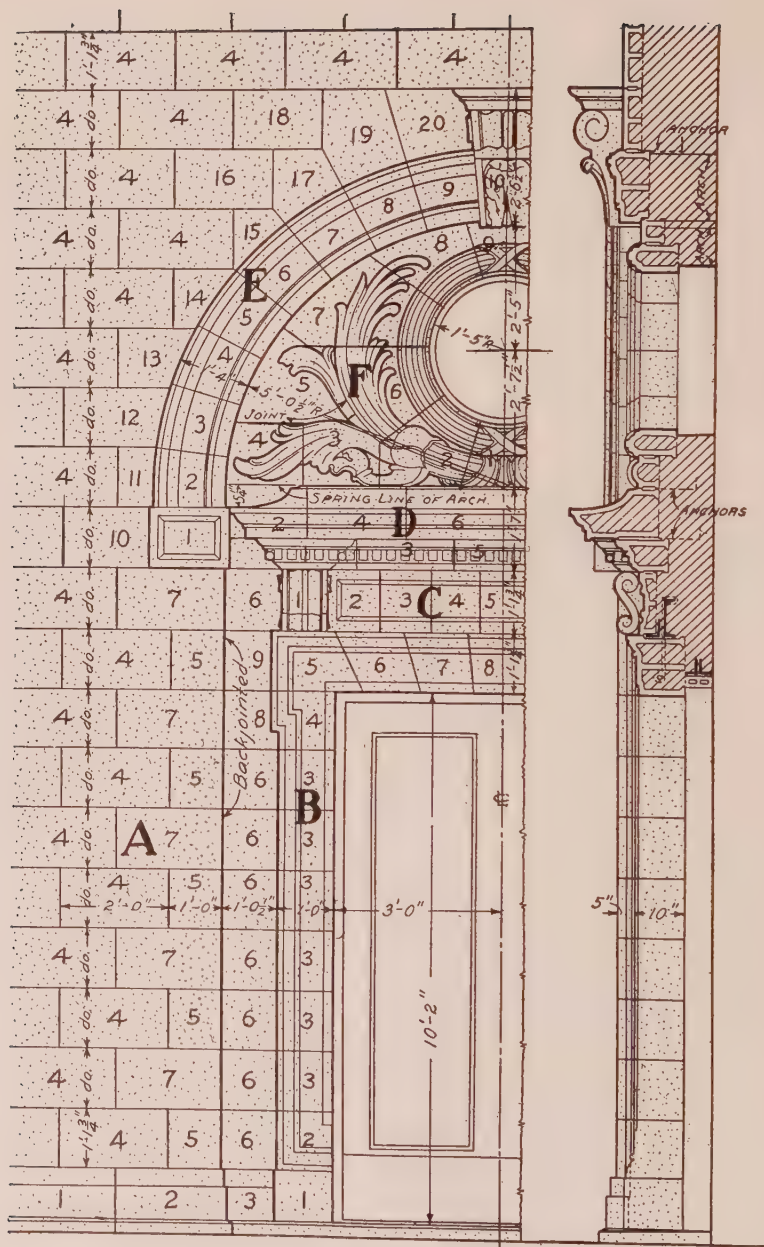
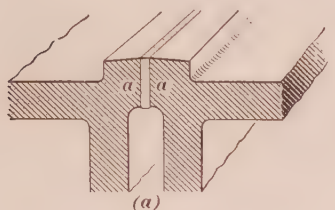
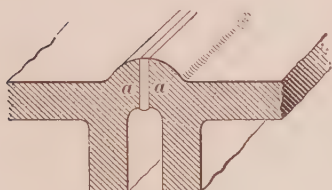


FIG. 14

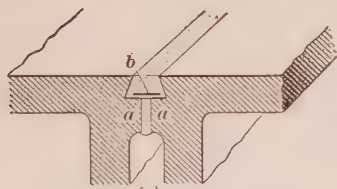
Any block marked *A 4* can be taken from the pile and placed in any position marked *A 4* in the setting plan. In the system shown in Fig. 13 blocks *A 4*, *A 10*, *A 16*, *A 22*, etc. are all of the same pattern and are interchangeable, but they must be carefully sought and laid in the rotation indicated on the plan. Thus the mechanic must look after fifty or more numbers instead of eight or ten.



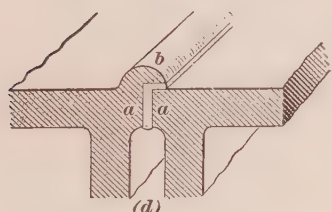
(a)



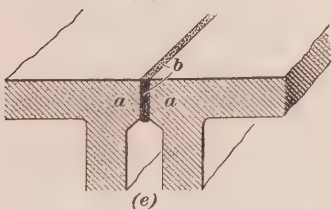
(b)



(c)



(d)



(e)

FIG. 15

DETAILS OF CONSTRUCTION

59. The process of designing terra cotta, of making the various drawings required, of modeling, and of the manufacture of the blocks having been described, some of the details of construction, which are peculiar to this material, will next be considered.

60. Forms of Joints.

The joints considered in this article are the abutting or connecting surfaces of the various blocks, and not the spaces filled with mortar between the blocks. The character of these joints is peculiar to terra cotta. The straight joint is illustrated in Fig. 12. These joints must be made so as to allow of grinding or chiseling off the joints when

the block has not shrunk to the degree calculated upon or is so

warped that trimming of the joints is necessary to make the face of the block true. As it would be difficult and expensive to grind the entire surface of the block, the joints are designed to be formed by the edges of the block, which are slightly raised so that any fitting that may be required may be done on the narrow surfaces *a*, *b*. The depressed spaces behind these narrow edges are filled with mortar.

61. Another characteristic form of joint is that required on the top surfaces of cornices, copings, string-courses, window sills, or any other surface upon which rain or snow may fall. These joints are illustrated in Fig. 15 (*a*), (*b*), (*c*), (*d*), and (*e*), which show five customary forms of such joints.

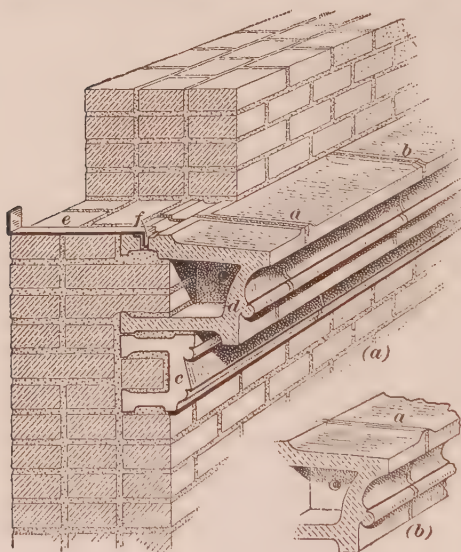


FIG. 16

In (*a*) is a *rectangular raised joint* and in (*b*) a *segmental raised joint*. The raised portions prevent water flowing into the joint. Both these forms are extensively used, and, where the opening

between the blocks is well filled with mortar, prove very satisfactory.

In (*c*) is shown a *recessed*, or *dovetailed*, form of joint. A piece of sheet metal *b* is usually inserted to form a base on which the mortar may rest and to prevent the mortar passing through the smaller opening below. The mortar of these joints is finished flush with the surface of the block.

In (*d*) is shown the *roll joint*, or *covered joint*. This form of joint affords better protection to the mortar joint between

the blocks than any of the other forms described. The roll *b* is, however, often broken or injured in handling or shipping, or is forced off by the action of frost which necessitates repairs that always prove unsightly. The use of this style of joint is therefore not to be recommended.

In (*e*) is shown a *butt joint*, such as used in stone and marble work and is highly recommended for use in terra-cotta con-

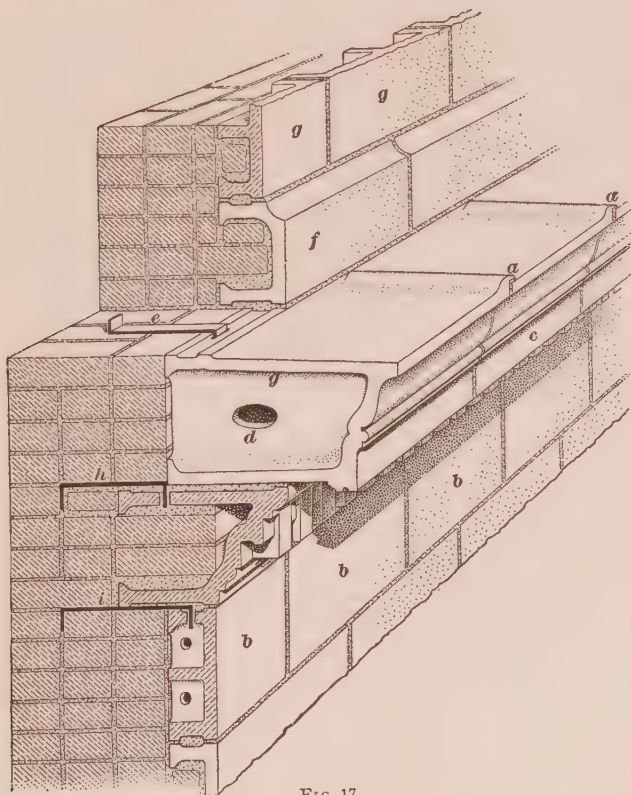


FIG. 17

struction. The edges of this joint are not easily marred by handling and the joint can be calked with mastic *b*, without necessarily breaking the edges. This style of joint is to be preferred to the others, as it presents no thin projecting parts that can be easily broken off.

62. Examples of Joints.—In Fig. 16 (a) is shown a terra-cotta belt-course that is built into a brick wall. The upper part of this course has blocks that are formed with joints of the raised rectangular shape. At *a* is shown one of these joints finished straight with the edge of the block, while at *b* the joint at the edge is finished with a *cove*. By means of this form the

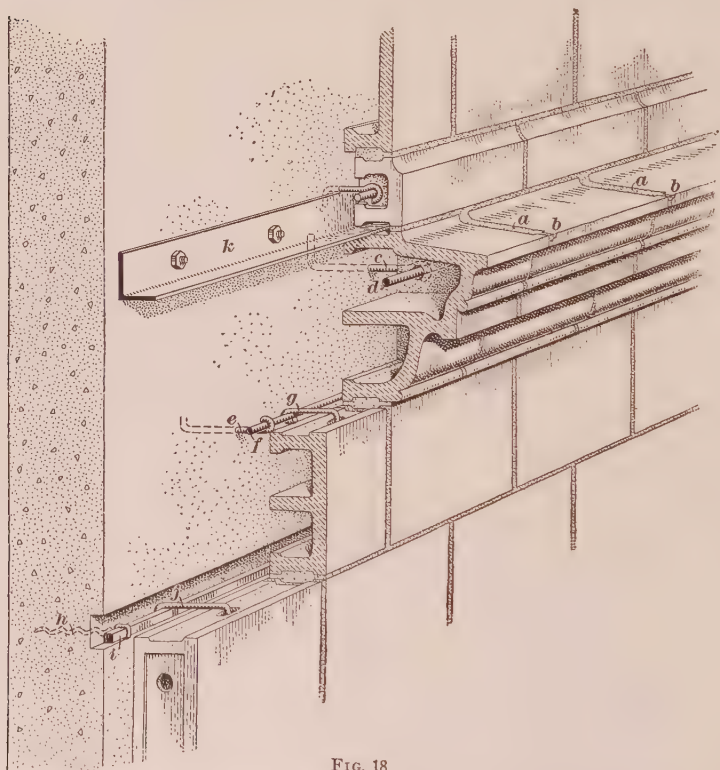


FIG. 18

joint projecting above the block is not apparent from below. At *a* in (b) is shown a segmental raised joint.

In Fig. 17 is shown a wall faced with terra cotta, and a projecting course also formed of the same material. The blocks of the projecting course have a roll, or covered, joint *a*. These joints, as well as the segmental raised joints, may terminate at the edge of the course with a cove as previously described.

In Fig. 18 are shown joints *a* of the dovetailed form. In this illustration it will be noted that at the front edge of the block, as shown at *b*, the joint is contracted to the same width as the regular vertical joint below.

63. Concealed Joints.—As the sizes of the blocks used in terra-cotta work are necessarily small, there will be a considerable number of joints. It is therefore desirable to conceal these joints when it is possible. This can often be done with vertical joints, which can be concealed at panel moldings, pilasters, window and door trims, etc. In concealing these joints, one block is rabbetted out so as to project in front of another piece, thus concealing the joint. These joints are considered as concealed as they are not visible to a person looking at the building casually.

In Fig. 19 is shown a concealed vertical joint between the blocks which form a paneled pilaster and the wall of a building. The block *a* is recessed on the back at *b* and the end of the block *c* is placed in this recess and thus made to fit closely. This method of treating joints is sometimes called *back-jointing*.

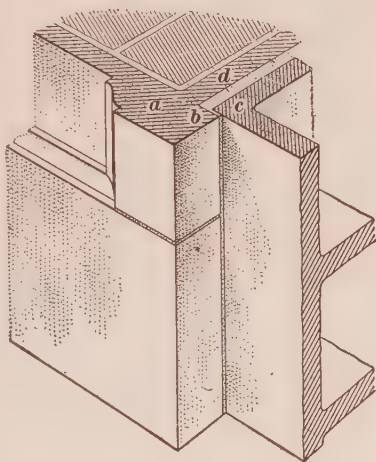


FIG. 19

Additional illustrations of concealed vertical joints appear later on in this Section in connection with the description of Columns and Pilasters.

64. Reglets.—Where a wall or a wall facing of terra cotta adjoins a roof construction, it is often necessary to place flashing and cap flashing against the terra cotta. The exact position of the roof should be shown on the plans and if it is found that the horizontal joints between the terra-cotta blocks will not serve to receive the upper edge of the cap flashing,

grooves, called *reglets*, should be formed in the terra-cotta blocks for this purpose.

In Fig. 20 is shown a parapet wall formed of the terra-cotta blocks *a* and coped with the blocks *b*. At *c* is shown a *reglet* that has been formed in the blocks adjoining the roof, and at *d*, is shown the edge of the cap flashing *e* placed in this reglet. After the cap flashing has been set into the reglet it is usually

secured by means of lead wedges *f* placed at intervals, and the remaining part of the reglet is filled with roofer's cement, as at *g*, to insure a waterproof joint.

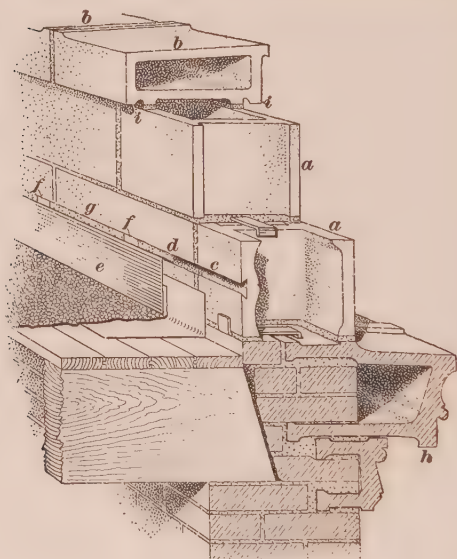


FIG. 20

directly down the wall. In Fig. 20 is shown a projecting cornice with a drip at *h*, and a coping with drips at *i*.

66. Securing Terra Cotta to the Structure.—Since terra cotta is generally a veneer, it must be fastened to and supported by the general structure in some way. There are two methods of fastening terra cotta to the supporting structure: First, by bonding the blocks into the wall; and second, by fastening it to the structure by means of steel work in the form of ties, anchors, channels, angles, etc. The forms of steel used in this work are shown in connection with the various details or forms of terra-cotta work next to be considered.

65. D r i p s .

Terra-cotta sills, string-courses, cornices and copings that project beyond the face of the wall below should have a member formed on the lower part, called a *drip*, that will cause the water to fall free from the wall and not run

67. Wall Facings.—In buildings of brick or stone masonry faced with terra cotta, the facing blocks are laid up like brick or stone, each course being embedded in mortar on the course below. Each piece is anchored with galvanized or painted iron wall ties embedded in the main wall or anchored to the steel frame to hold the terra cotta securely in place. Fig. 17 illustrates the application of a terra-cotta veneer to a brick wall, and shows the anchor *i* that holds one of the blocks in position against the wall. Most of the blocks are fastened to the wall in the same manner. The backs of the blocks are filled in solid with brickwork in cement mortar.

68. Wall Facings on Concrete Walls.—Fig. 18 shows the method of securing a terra-cotta facing to a solid concrete wall. In this construction the concrete wall is built first, and the anchor hooks, bolts, etc. are located and placed in the wooden forms in which the concrete is cast. In this system of veneering, the blocks are held in place entirely by the anchoring. It is therefore very necessary that the anchors be installed with great care.

69. Three systems of anchoring are shown in Fig. 18. In one system the hooked rod *c* is located so that it will come between the end shells of two adjoining blocks which are formed to fit accurately a horizontal round bar, as shown at *d*. This bar is sufficiently long to extend through the shells of both of the blocks and through the eye of the hooked bar. In this system, the hooked bars must be very carefully located so that they will come at these joints, otherwise they are not serviceable. In the second system of anchorage, the hooked bar *e* is turned around the horizontal bar *f*. This latter bar is located back of the blocks and the blocks are anchored at the top by pieces of iron as shown at *g*. As the bar *f* is continuous, anchors may be placed at any desired location horizontally. The vertical location of this rod must be accurately determined to insure proper connections being formed. The third system is illustrated in the lower part of the figure. At *h* is shown a heavy wire which is left projecting from the wall surface. By means of this wire, the rod *i* is attached to the wall and fits

into the recess that has been formed in the wall for this purpose. The method of anchoring the blocks to the rod *i* is shown at *j*.

70. When terra cotta is used as a veneer and cannot be filled with masonry, special precautions must be taken to avoid overloading the blocks and thus causing them to be crushed or the edges to be chipped. Where the space between the wall and the blocks permits of the pouring of concrete, this space and the blocks may be filled with a cement grout, but this work should be done as the work progresses and not after the wall has been completed to a story height.

Terra-cotta facings of the character mentioned are sometimes supported at intervals by means of angles such as shown at *k*, Fig. 18, called *shelf angles*. These are secured to the concrete structure by means of bolts which are placed in the concrete forms at the required locations before the concrete is poured, and after the forms have been removed the angles are attached to the wall by means of these bolts.

These angles must be accurately located and the lower flange should line with the horizontal joint in the terra cotta so that one course of blocks may have a direct bearing on the angle. The blocks resting on the angle should also be anchored to the angle, which is set away from the face of the building by means of washers. This permits of running wire behind the angle and securing the terra-cotta blocks in place, or of the use of bent rods such as shown in Fig. 18.

71. String-Courses.—String-courses are usually built into the wall as shown in Fig. 16. This example consists of two courses of terra cotta. The lower member *c* extends into the wall as far as the width of one brick and, since it has to support the weight of the construction above, it is filled in solid with brick and mortar. The upper course, shown at *d*, has a greater projection and also extends into the wall. Both these courses are filled with brickwork as far as the line of the wall face. The projecting part of the upper block is not so filled. Metal anchors of the form shown at *e* are used to tie the pro-

jecting blocks to the wall. The blocks have holes formed in the upper shell, as shown at *f*, to receive the anchors.

72. Cornices, Medium Size.—A medium-sized cornice is shown in Fig. 17. The wall supporting this cornice is faced with plain terra-cotta blocks *b*, equal in thickness to one thickness of brick. The cornice consists of two rows of blocks. The lower blocks are richly molded and have a considerable projection in front of the face of the wall. This course must provide a certain amount of support to the upper course and therefore must be filled with masonry and anchored to the backing by anchors such as shown at *h*. The blocks of the upper course *d* extend back into the wall so that they may have good bearings, or supports, and may be covered by the masonry above. This masonry resting upon the backs of the blocks prevents them from tipping outward. These blocks also support a considerable load of masonry, consequently must be filled with brickwork as far as the face of the wall. The projecting portion of this cornice is not filled with masonry, as it is desirable that this part be as light as possible so that it will have no tendency to drop or tip. The blocks in this course should be carefully anchored to the brick wall as shown at *e*. The course *f* projects in front of the face of the wall. Above this course the wall is faced with the blocks *g*.

73. Large Cornices.—Large projecting cornices of terra cotta usually require to be supported by the structural-steel frame or by the solid masonry walls of the building. Cornices that are designed for buildings having a steel frame usually have an interior framework of steel shapes, and this frame is connected with the frame of the building in such a manner that the entire cornice is supported by the steel work of the building. This form of construction is very complicated and the structural engineer who designs the frame of the building usually designs it so as to support the cornice properly. The terra-cotta manufacturer will then design the secondary steel members that are required for his work.

74. Cornices for solid masonry walls, such as those illustrated in Fig. 21, are usually so designed that the lower

members of the cornice will project somewhat to form a bracket or corbel on which the succeeding members, which have a greater projection, may rest. These lower members are filled with masonry and also anchored to the walls in the usual manner. The upper courses are provided with structural-steel forms *h* which are also anchored and secured to the wall. In this form of construction it is customary to extend the wall of

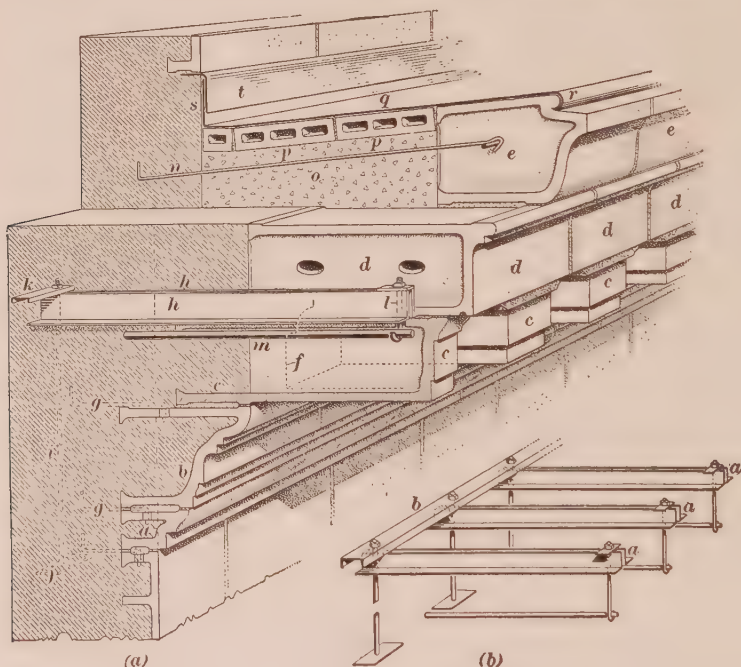


FIG. 21

the building to a sufficient height above the cornice to form a mass of material that will more than balance the weight of the projecting portions of the cornice.

75. The blocks that form this cornice are indicated at *a*, *b*, *c*, *d*, and *e* in (a). The outline of an additional block is indicated by the dotted line at *f*. This block cannot be shown in the view given, but occurs above the blocks *b* and fills the space between the brackets *c*.

The blocks *a* and *b* are filled with masonry and are also anchored by means of the tie-rods *g*. These blocks project beyond the wall surface and help to carry the brackets *c* and the wall blocks indicated at *f* between the brackets. The projection of the brackets *c* is so great, however, that the anchors and back filling are not sufficient to hold them in place. Steel angles *h* are therefore installed above each bracket to form a cantilever support. The angles are separated slightly to allow the rods to be placed between them for anchoring into the wall and for the suspension of the blocks. Wall anchors, one of which is shown at *i*, are provided to hold these angles in place and are usually several feet in length. Each anchor has a plate at the lower end, as shown at *j*, to anchor the rod to the wall. The upper ends of the anchors are fastened to the continuous channel *k* which runs parallel with the wall. By means of these anchors and fastenings, the steel angles are prevented from being pulled out of the wall by the weight of the cornice.

The bracket blocks *c* are supported and kept in place by a length of iron pipe *m* which is placed inside the bracket. One end rests on the brick wall and the other end is suspended from the channels by means of a rod *l*. This rod has a thread and nut on the upper portion. By turning the nut the bar *m* is raised until it comes in contact with the upper shell of the bracket and holds the bracket firmly in place. The blocks *d* are formed to fit over the angles *h* and rest on the brackets and the wall blocks between the brackets. The top members of the terra-cotta cornice, shown at *e*, rest on the blocks *d* and are anchored to the wall by rods, one of which is shown at *n*.

In (*b*) is shown a perspective of the steel work used in this system of supports with the various members assembled. The series of cantilever angles are shown at *a*, the continuous channel at *b*, and the anchorage and suspension rods as just described.

76. Lintels.—In Fig. 22 is shown an entrance to a building which has walls faced with terra cotta. The jambs and lintel of the opening are also formed of the same material. Since the terra cotta is only a veneer for the brickwork, it is necessary

that steel supports be provided to carry the terra cotta as well as the brickwork over the opening.

Fig. 23 (*a*) represents a section taken through the center of the lintel over the entrance shown in Fig. 22. The steel sup-



FIG. 22

ports that carry the masonry and terra cotta consist of three angles, as shown at *a*, *b*, and *c*, and one channel *d*. The angles *a* and *b* carry part of the brick wall, and the angle *c* and channel *d* carry the remaining part of the wall and the terra-cotta lintel. The steel member *d* supports the terra-cotta lintel

course *c*, which is suspended from the steel by means of rods *f* and anchored by the anchors *g* so that it is perfectly strong and rigid.

In this figure, sections are shown through the blocks which form the courses *c*, *h*, and *i* to illustrate how the blocks are formed to fit around the steel work and to show the rods and anchors that secure them in place. In (b) is shown a view of the steel supports *a*, *b*, *c*, and *d* that hold up the lintel. At *e* is shown one of the rods that carry the lower course of terra cotta. These rods are placed between the blocks of the lower course of the lintel, the upper ends of the rods are secured to the steel channel by means of clips *f*, and the lower end is bent around the short bar *g*, which extends through the end shells of two adjoining blocks. At *h* is shown a rod which is formed around the bar *g* and also over the horizontal flange of the angle *a*. This rod prevents the block from tilting when the succeeding course of terra cotta is put in place on top of it. At *i* and *j* are shown the galvanized iron bars that are used to anchor the terra-cotta blocks *h* and *i* in (a) to the steel lintels.

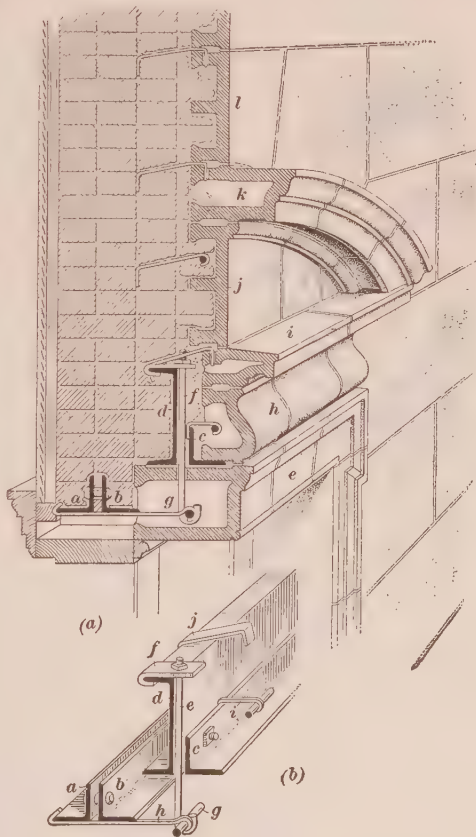


FIG. 23

The terra-cotta blocks *j*, *k*, and *l* in (a) are bonded with the brick wall and also anchored by bars as in the regular form of construction.

The terra-cotta lintels of the entrances shown in Figs. 2, 3, and 5 are all formed of courses of blocks and carried by steel members that are concealed in the masonry, thus permitting the exposed under side of the lintel, called the *soffit*, to be finished to correspond with the jambs, as is shown in Fig. 5. The principle involved in the construction of these

lintels is the same as that shown in Fig. 23, the form of the blocks and the steel work being adapted to meet the requirements of the different designs.

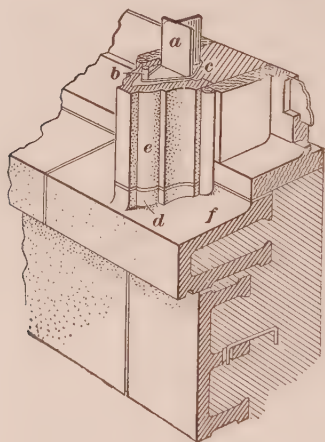


FIG. 24

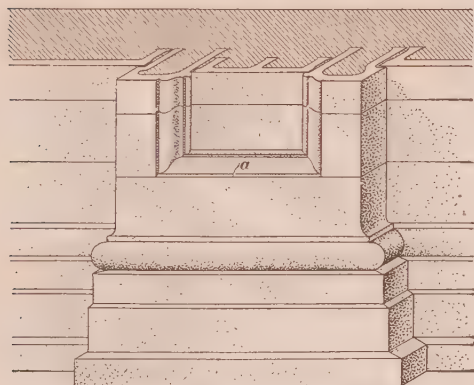
77. Window Mullions.

Window mullions or slender piers that are formed of terra cotta or have a facing of that material, should be provided with steel posts formed of **T**'s, angles, or gas pipe, to which the terra cotta may be anchored, and which will give stiffness to the piers.

In Fig. 24 is shown a mullion that has a terra-cotta facing. A steel **T** bar *a* is used to reinforce the mullion. A short iron bar *b* is placed in an opening in the top of the terra-cotta block and this is anchored to the **T** bar by means of a heavy wire. The bar *b* extends into the bottom shell of the succeeding block. Round or square bars of iron are sometimes used as anchors, one end being formed to turn down into the opening in the top of the block and the other end being formed to fit around the **T**. This method, however, does not anchor the bottom end of the succeeding block.

In this illustration it will be noted that the lower part *d* of the mullion is formed on the terra-cotta sill-course. This is done to secure a level bearing for the block *e*, as the sill is formed with a slope, as shown at *f*.

Examples of mullions which have steel reinforcement are



(a)

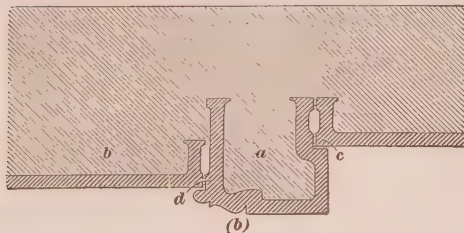


FIG. 25

shown between the windows over the front entrance of the bank building illustrated in Fig. 3, between all windows of the residence shown in Fig. 7, and between the windows of the apartment building shown in Fig. 8. This reinforcement is absolutely necessary for the mullions shown in Fig. 7, as the mullion is too small to permit of sufficient masonry backing to give any strength to the terra cotta or to permit of anchoring the various mullions. The transom blocks which form the bars shown in this illustration are also reinforced with steel.

78. Pilasters.

In designing pilasters, the forms of the blocks and manner of jointing them where they intersect with wall blocks require particular consideration in order that the

vertical joints may be concealed or, at least, not easily seen.

The pilaster shown in Fig. 25 has a paneled face and each course in the width of the pilaster is formed of three pieces. The panel is formed of one piece and the side members of the other pieces. At *a* in (b) is shown a plan of one side piece, and at *b* a portion of the panel. At *c* and *d* the manner in which the block is formed to conceal the vertical joints is shown. The moldings at the top and bottom of the panel, as

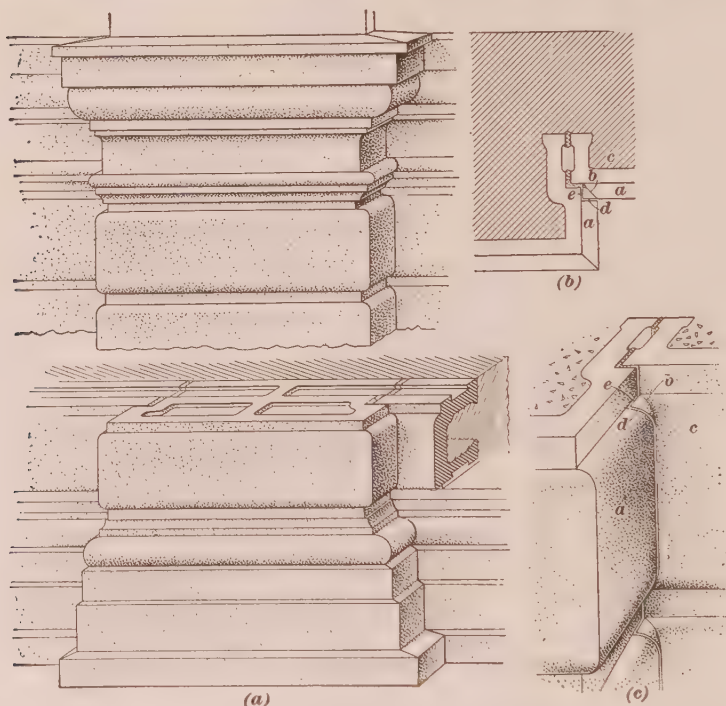


FIG. 26

shown at *a*, *a* in (a), are formed on the same blocks as the top and bottom sections of the panel.

The pilaster shown in Fig. 26 has horizontal joints known as *rusticated joints*. This is a very practical design for large blocks, as a slight warping of the blocks in the burning is less apparent than in the plain smooth-faced pilasters. In the rusticated design, the horizontal joints between the blocks are not conspicuous, as they are located at the tops of the recessed

surfaces between the projecting parts of the blocks. This design requires a somewhat different form of joint, however, at the intersection of the pilaster with the wall, as one part of the block projects beyond the other portions. In (b), at *a*, are shown these projecting parts, and at *b* is shown the return which is formed on the wall block *c*. In (c) is a view of this joint, showing the projecting part of the wall block *c* extending behind the similar portion of the pilaster block. The portions *d* and *e* of the joint will appear as shown. These joints should be made as thin as possible so that they will not be easily seen. This form of block allows of a square joint between the two intersecting blocks instead of a miter joint, and any cutting of the blocks that is necessary to make them fit properly may be easily done without disfiguring the joint.

79. Columns.—Columns of terra cotta are built up in sections from 10 to 16 inches in height, called *drums*, from their cylindrical drum-like shape. For columns not exceeding 14 inches in diameter these drums can be made in single pieces.

In the case of columns of large diameter, it is not practical to make the drums in one piece, as slight inequalities of shrinkage are likely to occur. The best practice is to use a sufficient number of vertical joints to make the drum of four or more pieces, depending upon the diameter of the column. The vertical joints should be continuous for the whole length of the shaft wherever practicable. The heights of the courses should not exceed 16 inches.

If the terra-cotta column is to enclose a structural-steel column, the drums must be made in pieces so that they can be placed around the steel column.

80. In Fig. 27 (*a*) is shown a terra-cotta column of small size, in which the drums can be made in one piece if desired. The drums are shown at *a*, *b*, *c*, etc. The drum *b* is in one piece, and *a* and *c* are each in five sections. A plan of the drum *b* is shown in (*c*) and a plan of the drums *a* and *c* in (*b*). The plan (*b*) shows the outer shell upon which the flutes are cast, also the radiating webs and the vertical joints between the sections. The right-hand side of the plan shows

the top of the block with anchors *d* holding the blocks together, also the raised parts of the bed joints *e*, which are ground

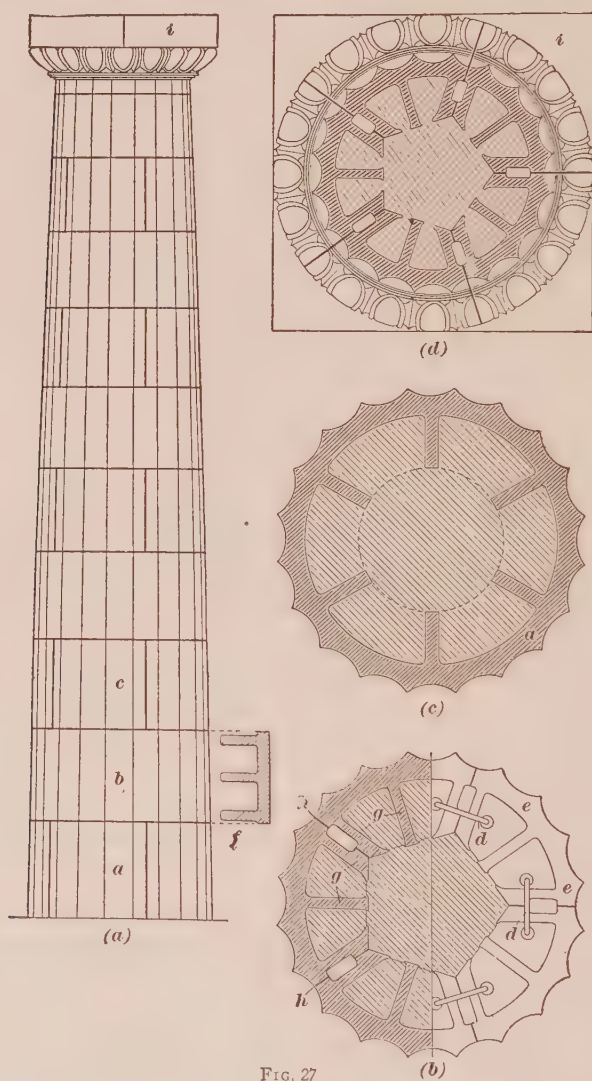


FIG. 27

when necessary to make the blocks fit together. At *f* in (a) is a vertical section through a block, showing the horizontal ribs

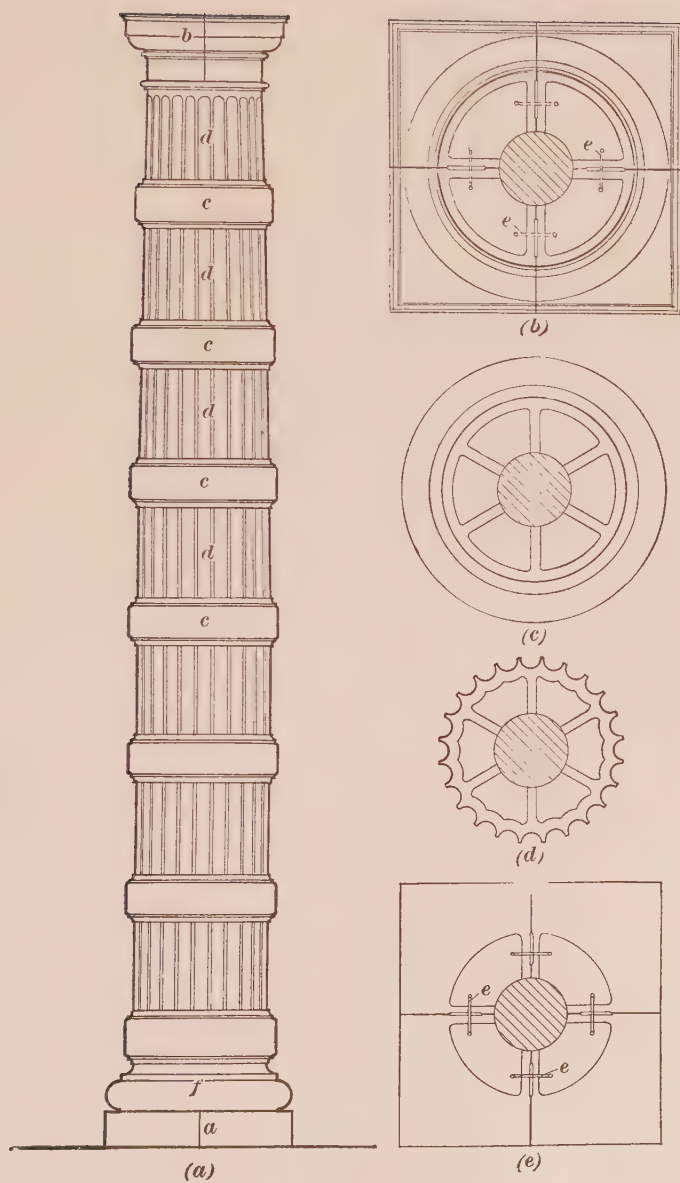


FIG. 28

and the raised joints that are shown in plan at *c* in (*b*). The left-hand side of the plan (*b*) shows the radiating webs *g* and the joints *h*. The capital is generally made in sections. A plan of the capital of the column, in which the observer is looking upwards, is shown in (*d*). The ornamental portion of the capital is divided into five parts and the square abacus *i* into four parts.

81. When the column is built, the center of the column as well as the hollow spaces in the block are filled with masonry. Concrete is the cheapest and best material to use for this purpose. A column such as the one just described is not strong and should not be expected to support a great load. When there is a considerable load to be supported a steel column should be placed inside the terra cotta one in the manner that will be described later in connection with Fig. 29.

82. A design of column known as a *banded column* is shown in Fig. 28 (*a*). With the exception of the base *a f* and the capital *b*, the sections that form this column are all of the drum shape, made without vertical joints. The advantage of this design, for terra-cotta construction, is that the plain sections *c*, being located between the fluted sections *d*, conceal irregularities in the flutes that may be caused by the burning and which would be apparent were these fluted sections placed together. The forms of the shell and the interior webs of this column are similar to those of the column shown in Fig. 27.

A plan of the base block *a* in (*a*) is shown in (*c*). A plan of the cap viewed from the under side is shown in (*b*). Both base and cap are formed of four pieces which are clamped together as shown at *e* in both these figures. The clamps are shown in dotted lines, as they occur on the upper side of the capital and could not be seen in the view given. A plan of the circular portion *f* of the base is shown in (*c*), and the plan (*d*) represents the fluted drums *d* in (*a*).

83. Columns that are required to support a weight in excess of the load the terra cotta will safely carry should be provided with a structural-steel column in the center. If the terra-cotta column is small and the sections are in single drums

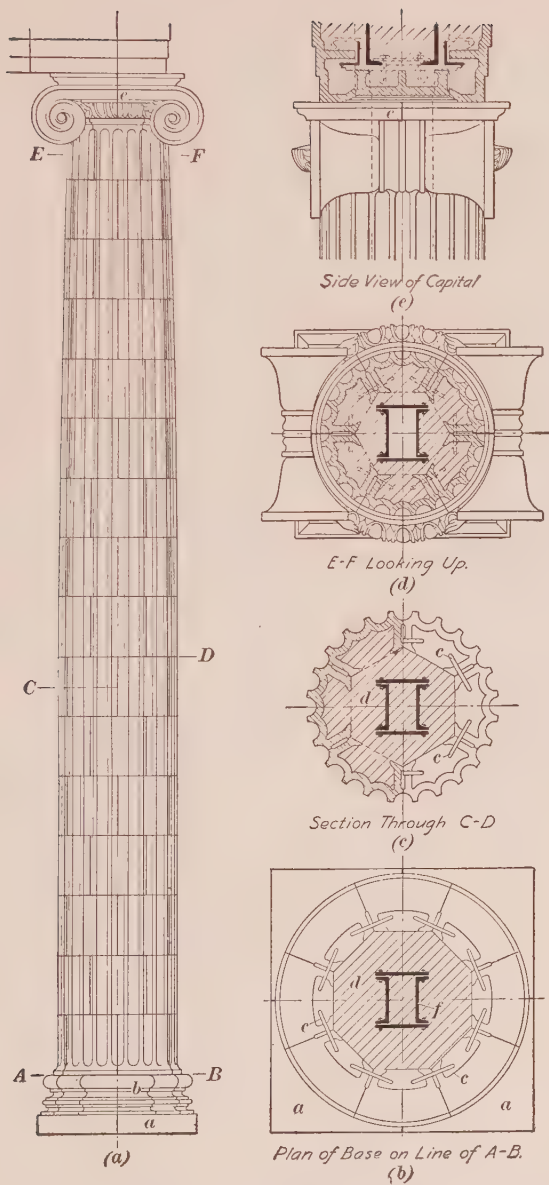


FIG. 29

it will be necessary to erect the steel column first and lower the terra-cotta drums down from the top over the steel column.

Columns of large dimension cannot be economically or successfully formed in single drums, but must be built up of segments. Columns of this character usually contain structural-steel supports, and the terra-cotta segments must be designed to fit around the steel work which has been previously erected.

To conceal the vertical joints as much as possible in the completed column, frequently flutes and beads are employed in the design and the vertical joints are located in these members. Segments that form the columns should be anchored together by means of iron clamps hooked down into holes cast in the shell or webs of the units and the hollow spaces in the blocks should be filled with brickwork or concrete.

84. In Fig. 29 (*a*) is shown a fluted column having a molded base and an ornamental capital. This terra-cotta column encloses a steel structural column and is of a large diameter. The base, shaft, and cap are formed of several units and the joints between them are indicated in the illustration by heavy lines.

In (*a*) is shown the complete column. The base block *a* is formed of four parts, as in the square part of the base shown in Fig. 28. The molded base *b*, Fig. 29 (*a*), is shown in plan in (*b*) and is formed of eight segments which are bonded together by means of iron clamps *c*. A section through the fluted shaft of the column, taken on the line *CD* in (*a*), is shown in (*c*), six segments being used to form the drum. These are also anchored together by means of clamps *c*.

The right-hand part of this section is taken through the joint and therefore the clamps *c* can be seen. The left-hand side of the section is taken through the middle of the block and shows the concrete or cement filling at *d*. A plan of the under side of the cap, taken at *EF*, the observer looking up, is shown in (*d*); the heavy lines indicate the jointing of the four parts that form the cap. Joints on one side of the cap are shown at *e* in (*a*) and those of the other side of the cap are shown at *e* in (*e*).

The steel column around which the terra-cotta column is formed is shown at *f* in (*b*), and the space that is filled with concrete or brickwork is shown at *d*.

An example of cylindrical columns formed of plain blocks of terra cotta is shown in Fig. 3. In Fig. 2 are shown columns that have structural-steel members in the cores. These columns are designed so that the vertical joints between the blocks occur

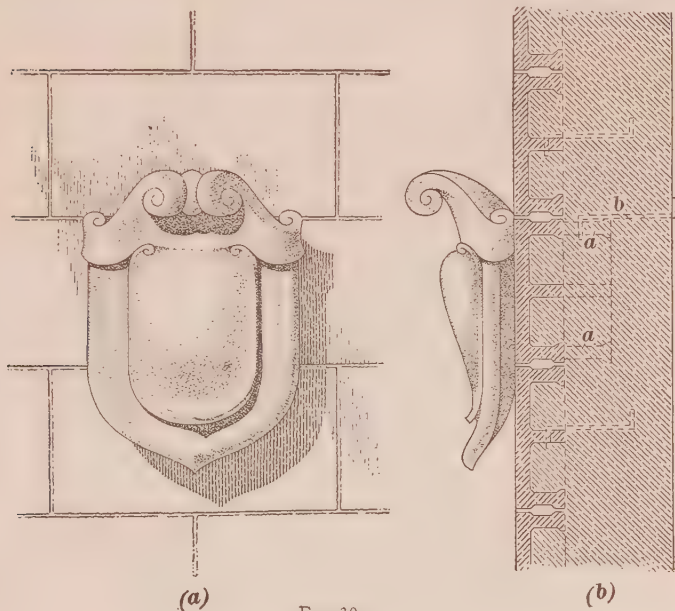


FIG. 30

at the angles of the columns and are thus partly concealed by an ornamental beaded treatment.

85. Cartouches.—A cartouche is a form of ornament consisting generally of a panel in the shape of a shield, oval, or rectangle, which is surrounded by ornaments consisting of ribbons, scrolls, foliage, etc. The central panel may be decorated with a coat of arms, a motto or some similar motif, or left plain. Cartouches are used frequently as a means of decoration and their ornamental character makes them expensive to execute in stone. They are, however, comparatively inexpen-

sive when made of terra cotta. A small cartouche is shown in Fig. 30. An elevation is shown in (*a*) and a side view in (*b*). The method of securing the cartouche to the wall is shown in (*b*), in which the block, of which the cartouche is a part, extends back into the wall as shown at *a*, and an anchor *b* firmly secures the cartouche to the wall.

86. Cartouches are often quite large and made up of several blocks. The joints in such cases are carefully designed so



FIG. 31

as not to cross the principal parts of the cartouche. An example of a large cartouche is shown in Fig. 31. Joints are shown on each side of the helmet and in corresponding positions in the lower part of the cartouche. The shield containing the eagle is in one piece, as a joint through this part of the cartouche would be unsightly.

87. A very conspicuous example of the use of terra-cotta cartouches in the design of the building is shown in Fig. 8. In this design cartouches form the central parts of ornamented panels, as in the panel immediately over the entrance to the building; in other places they are used as inserts in the wall.

88. Balustrades.—Vertical members of terra cotta, such as balusters, urns, finials, etc., are usually formed of small pieces and held together by round iron rods extending up

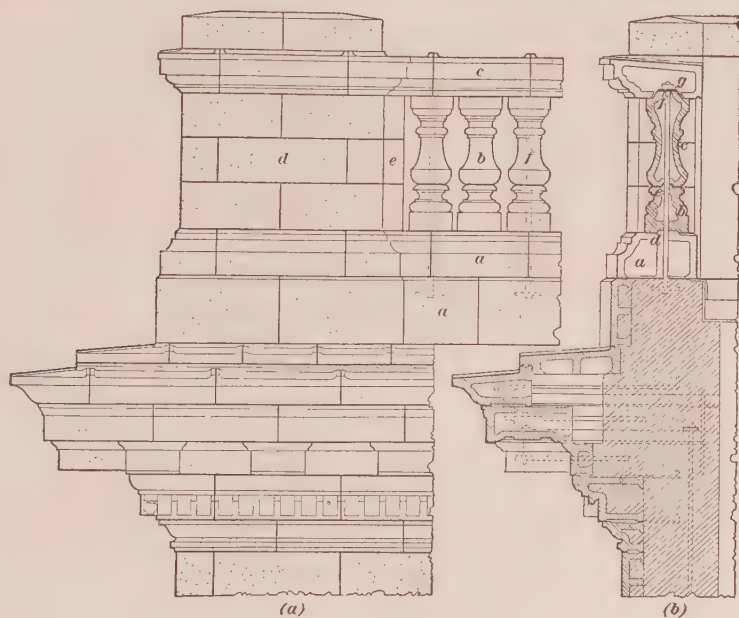


FIG. 32

through hollow cores in the centers. On each end of these rods is a nut and washer, and when the top nuts are tightened the different pieces of terra cotta that compose the baluster or finial are drawn closely together.

When balusters are short, each can be cast in a single piece having a hollow core to receive the rod and to permit of proper shrinkage in the burning. Long balusters can be molded in halves, which, after drying, are placed together and the joints smoothed off and finished so they will not show. The com-

pleted baluster is then placed in the kiln and burned. When a long baluster consists of a base, shaft, and cap, however, joints are formed in the baluster so that it may be cast in three pieces, each of which is small. The twisting and warping due to burning is thus reduced to a minimum.

Balustrades are formed of a series of balusters which rest on a terra-cotta base and are covered at the top by a terra-cotta cap, or railing, and the balusters are anchored to this base and cap to make a strong and rigid construction.

89. A portion of a balustrade of this description is shown in Fig. 32 (*a*) and a section through the balustrade and one of the balusters is shown in (*b*). In (*a*) an elevation of the base on which the baluster rests is shown at *a*, the baluster at *b*, and the cap, or railing, at *c*. The balustrade terminates at the end of the building in a pier as shown at *d*. This pier is faced with regular-shaped terra-cotta blocks and is constructed in the same manner as terra-cotta faced walls. At *e* is a plain pilaster adjoining the pier.

The dotted lines at *f* indicate a rod that extends from the base, through the baluster, and into the cap. In this illustration the rods are inserted in every other baluster instead of in each one. In (*b*) is shown a section through the balustrade in which the baluster is shown to be formed of two parts, *b* and *c*. Dowels are formed on the base *a* and also on the members of the baluster which fit into corresponding recessed parts as are shown at *d*, *e*, and *f*. At *g* is shown a flat bar that extends the entire length of the balustrade and through which the rods pass and are secured. This portion of the balustrade requires to be completed before the cap members are set in place.

90. Domes.—Architectural terra cotta has come into wide use as a facing material for the interior and exterior surfaces of domes. It is particularly adapted to this use because the material is light in weight and permits of extensive color effects, and is impervious to the weather.

The terra-cotta facing is supported on a frame made of rolled-steel sections of light weight, or, more generally, on a light concrete dome which may or may not be supported on

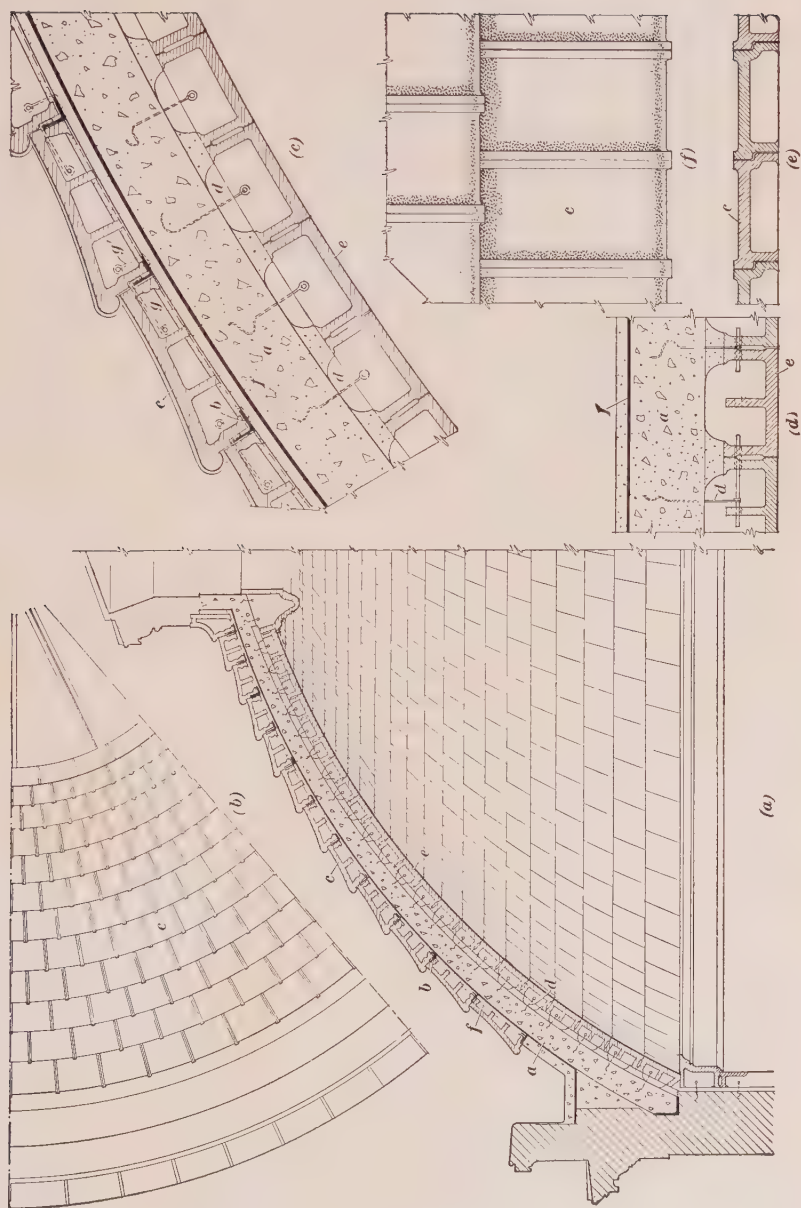


FIG. 33

steel shapes. Fig. 33 shows the construction of a dome made of concrete which is faced both on the outside and on the inside with terra-cotta blocks. In (*a*) is a cross-section through one half of the dome and in (*b*) is a plan of part of the outside terra cotta. The reinforced concrete which forms the structural base on which the terra cotta rests is shown at *a* in (*a*). The steel angles to which the outside terra-cotta work is attached are shown at *b*; the exterior terra-cotta blocks *c* rest on the angles as well as on the concrete and are also wired to the angles.

The blocks used on the outside of the dome have lips that project over the next row of blocks below. The vertical joints between these blocks are rectangular raised joints, as shown in (*e*) and (*f*). A dome constructed in this manner should have a waterproof coating of felt and tar above the concrete and under the terra cotta to prevent water from working its way through the dome from any leaks that may occur in the raised joints of the outside terra-cotta covering. This waterproofing is indicated at *f* in views (*a*), (*c*), and (*d*). All the outside joints should be filled with roofer's elastic cement to insure their permanence and waterproofing value.

A section through the individual blocks is shown at *c* in (*c*). The steel angles *b* support the blocks which rest against them, and, in addition, the blocks are wired to the angles as shown at *g, g'*. These wires extend between the joints of the blocks and are secured to pins that pass into holes in the adjacent blocks. A section through the raised joints is shown in (*e*). The wire just referred to is placed in the joints between the blocks. The joint is rabbetted, which tends to make it waterproof, but should nevertheless be filled with good elastic cement. The tiles themselves are also set in elastic cement.

The inside lining of the dome, as shown in Fig. 33 (*a*), is formed of blocks *e* secured to the concrete dome by means of stout wires *d* that are set in the concrete when it is cast. These wires, shown more clearly in (*c*) and (*d*), extend below the lower surface of the concrete and their lower ends are fastened to short rods that extend through holes that occur in all the blocks and thus the blocks are held securely in place.

SHIPPING AND HANDLING TERRA COTTA

91. Packing.—Terra cotta is usually shipped from the factory in box cars, as they afford better protection for the blocks than open cars do.

The blocks should be carefully packed with plenty of hay or straw surrounding them. They should be laid in courses in the car and be so placed that no finished edges or faces come in contact with the car or adjoining pieces. All blocks should be so braced or wedged with the straw or hay that they cannot move about in the car.

The courses, or layers, in the car should consist of blocks having consecutive numbers, so that when the blocks are removed from the car upon its arrival at its destination they may be stacked in corresponding layers, or courses. This method will facilitate finding the blocks in their proper order when they are to be placed in the wall.

92. Receiving and Checking.—When shipping the terra cotta, the manufacturer always sends to the contractor who is to erect the material a list of the pieces included in the shipment.

When the blocks are received at the building they should be checked with the list, and if any listed pieces are missing, the factory should be notified immediately so that the pieces needed may be shipped without delay.

93. Assorting and Stacking the Blocks.—As there is danger of the terra cotta being chipped by frequent and careless handling, it should be assorted as it is received at the building and stacked in such a manner that it will not need further handling until it is required to be placed in the walls of the building. For this reason it is customary to form separate stacks of the blocks that form each part of the design, and to place the blocks that are required first at the top of the stack.

In stacking the blocks, care should be taken to prevent all edges and finished faces from coming in contact with hard substances or with one another. The best method is to pile the pieces in layers with strips of boards between the layers.

If blocks are not to be used immediately, they should be stored in a shed or be covered with boards and waterproof paper to prevent their being injured. If a block is broken it will take from six to eight weeks to send to the factory and duplicate it.

94. Handling the Blocks.—In conveying the blocks from the stacks to the scaffold, the pieces should be carried singly, if possible, one block of ordinary size being a good load for one man. If it is necessary to use a wheelbarrow, the block should be placed on straw with the face up and only one block should be carried at a time, unless the blocks are very small. In that case several small blocks may be placed in the wheelbarrow, provided that straw is carefully packed around them.

SETTING THE TERRA COTTA

95. Backing-Up the Blocks.—Terra cotta is backed up with masonry in much the same manner as cut stone or face-brick work. When terra cotta is used as a veneer for a masonry wall, the hollow spaces in the blocks are generally filled with masonry. When the terra cotta projects beyond the face of the wall, the masonry filling of the blocks usually does not extend very much beyond the face of the wall, consequently steel anchors, such as have already been described, are used to tie the terra cotta to the masonry. These anchors if not embedded in masonry should in all cases be covered with cement grout as a protection against rust. It is dangerous to omit this protection.

Terra-cotta facings for concrete walls frequently do not permit of filling the back of the blocks with masonry, but grout may be poured back of the blocks to fill the voids, if the circumstances require it.

96. Fitting.—While terra-cotta blocks are usually fitted together and the edges jointed at the factory, occasions arise when it is necessary to cut the blocks at the building before they can be set in place. This may be due to errors in measurements or to irregularities in the structural parts of the building.

The shells and webs of the blocks sometimes require to be cut to fit structural-steel members or to provide additional openings into which anchors may be placed. This cutting should be done only by skilled workmen and every precaution should be taken not to injure the block either on the exposed face or in the parts that are essential to its strength and anchorage. It is, however, not often necessary to fit the terra cotta at the building.

97. Anchoring.—The method of anchoring terra-cotta blocks will depend upon the form of the blocks and the structure to which they are to be attached and must be adapted to meet the peculiar requirements of each case.

The most essential feature of the anchor, next to its strength, is that it shall form a rigid connection between the block and the backing to which it is fastened. The manner in which it is made rigid will depend upon whether the anchor is of a form that can be adjusted or one that is of a fixed form.

Horizontal anchors that connect with the blocks and extend back into the masonry do not require to be adjustable. They are set into the holes of the blocks and masonry is built around the opposite ends so that when the mortar becomes hard the anchors cannot be moved.

Anchors that fit over a structural-steel member back of the block are sometimes formed by bending one end to fit into the block. The anchor is then placed in position and by means of a hammer, the opposite end is bent so that it will accurately fit over the steel. This method is possible only where the anchors are formed of small bars or straps that can be bent without endangering the terra-cotta blocks.

When heavy anchors are used to fit over structural-steel members, they may be formed with turned-down ends and of such lengths that they can be easily driven into position. They may be made slightly longer than required, and when set in place may be wedged at either end by means of small pieces of broken terra-cotta blocks until they are rigid, after which mortar should be slushed around the anchor connection at the block to make sure that the anchor will remain in place.

For overhanging blocks that are carried by suspension rods, an adjustable form of hanger is used. The lower end of the rod is formed with a hook through which a bar extends horizontally into adjacent blocks. The upper end of the suspension rod is provided with a screw thread and nut. The horizontal bars afford a bearing for the terra cotta and the suspension rods are brought to a rigid condition by screwing down the nuts on the upper ends. In this manner the entire weight of the block is carried by the rod.

98. Bedding in Mortar.—All terra-cotta blocks should be well bedded in mortar and pressed down so that each piece will have a uniform bearing throughout the length of the block. Mortar joints for the top surfaces of all sills, projecting courses, cornices, and copings should be carefully formed so that no openings will be left through which water may enter the joints.

In setting heavy pieces of terra cotta, wooden wedges of uniform thickness are sometimes placed in the mortar bed to secure joints of uniform sizes, as the weight of the block would otherwise cause the mortar to be pushed out of the joint before the mortar becomes hard.

The mortar joints at the face of the wall frequently are finished as the blocks are laid, instead of being pointed later. When this is to be done, a rough mortar joint is formed with the trowel when the block is put in place and in the course of several hours, when the mortar has become sufficiently hard, it is smoothed with a tool to secure the form of joint desired.

99. Filling.—For large projecting cornices, such as shown in Fig. 21, concrete is sometimes used as a filler, as shown at *o*, instead of terra cotta.

On this filler is placed a row of regular building tiles *p* to form a surface on which the sheet-metal covering *q* may be laid. This covering extends over the front member of the cornice and returns into a groove, or reglet, that has been formed in the face of the blocks, as shown at *r*. It is secured in place by means of wedges of lead and the intermediate spaces are filled with roofer's elastic cement. At the wall, the

sheet metal turns up as shown at *s*, and is cap-flashed in the usual manner, as shown at *t*.

100. Mortar.—Mortar for setting of terra cotta is usually formed of cement and sand, with a small amount of thoroughly slaked lime added to make the mortar more plastic and thus facilitate its spreading. Mortar for this purpose should be composed of one part Portland cement and two parts of clean sand and $\frac{1}{10}$ part of hydrated lime.

Lime mortar is not suitable for this form of construction, as it sets slowly and therefore prevents rapid progress with the work, for the weight of the terra cotta would squeeze the mortar out of the joints before it had time to become hard. Lime mortar will, moreover, disintegrate in time and leave open joints.

When the joints in the terra cotta are to be pointed after the work has been completed, the mortar in the joints should be raked out to a depth of from $\frac{1}{2}$ inch to 1 inch as soon as the blocks have been set. Also, loose particles of mortar on the face of the blocks should be removed to facilitate cleaning the blocks later on.

101. Protecting the Terra Cotta.—All projecting members of terra-cotta courses should be temporarily protected after the blocks are laid, so that they will not be broken by falling bricks or other building material. Planks or boards are used for this purpose and it is usually specified in the carpenter's, mason's, or the terra-cotta contract, that the contractor shall protect all terra-cotta work until completion of the building. A board slightly wider than the projection should be laid along all projecting members and fastened securely in place by crosspieces tacked to window frames, floor joists, or wherever it is possible to make a fastening. Ornamental panels or other ornamental terra-cotta work should be entirely covered to make sure that they will not be injured during the process of building.

102. Terra-Cotta Foreman.—For a large or complicated job of terra cotta, a terra-cotta foreman, who is an expert

in this work, is sometimes employed, at the owner's expense, to supervise the terra-cotta work.

It is the duty of this foreman to see that the material arrives on the building site at the proper time and in sufficient quantities so that there will be no delay in erecting the building. He also checks off the blocks to see that they are all at hand and causes them to be piled in such order that they can be taken as wanted without unnecessary delay or lost labor.

He is responsible for the proper stacking of the blocks to keep them from injury and for seeing that they are covered up and protected with planks or boards. The supervision of the actual setting of the blocks is also part of the duties of the terra-cotta foreman.

103. Washing and Pointing the Terra Cotta.—As a general rule, terra-cotta blocks are laid up without the joints being pointed, the rough mortar of the joint being raked out slightly before it becomes hard. Just before the completion of the building, the face of the terra-cotta work is washed and the joints pointed. This work can be done by the masons who set the terra cotta or by another contractor who is a specialist in this line of work. The latter is the usual practice for cleaning buildings composed of brick or stone walls and terra-cotta trimmings, and one contractor is then responsible for the cleaning and pointing of the face of the entire building.

Unglazed terra cotta should be washed with a weak solution of muriatic acid such as is used in cleaning brickwork, a 3-per-cent. solution being sufficiently strong for this work. This may be applied with a coarse brush and the surface of the terra cotta scrubbed until all cement stains and lumps have been removed. Steel brushes, such as are used in cleaning stone and brickwork are not suited for cleaning terra cotta, however, as the steel bristles may injure the glaze of the material. Steel or iron tools, pails, etc., should never be used in connection with acid in cleaning the fronts of buildings. Glazed terra cotta never requires acid. The best cleaning material to use is an abrasive soap or washing powder. Lumps of mortar should be soaked with water and removed with a wooden stick.



Courtesy of the Atlantic Terra Cotta Company

FIG. 34



FIG. 35



FIG. 36



FIG. 37



FIG. 38

The pointing materials may be ordinary cement-and-sand mortar, white-cement mortar, or colored cement mortar, as may be desired. For white enameled terra cotta, white mortar is generally used to make the joints as near the color of the terra cotta as possible. Pointing mortar may be colored any desired shade to match any color of terra cotta, but mineral colors only should be used, as coloring matter composed of vegetable colors will fade.

Joints in terra cotta are usually close, and the pointing is done with a tool about an eighth of an inch in thickness. This tool makes a joint that is slightly depressed at the center and the mortar is pushed firmly against the edges of the blocks.

EXAMPLES OF TERRA-COTTA WORK

104. One of the most noteworthy examples of terra cotta applied to the exterior of a building is shown in Fig. 34, which is a view of the Woolworth building in New York City. The general color of this building is a light cream, while the panels between the windows are finished in various colors such as golden yellow, green, sienna, and blue. The style of architecture employed is Gothic. The terra cotta, which is mat-glaze finish, was set in mortar composed of cement, white sand, and a waterproofing compound. The building was washed down with Gold Dust washing powder and sand grit, no acid being used in cleaning.

105. Notwithstanding the lightness and delicacy that characterize the appearance of this building, the details when seen at close range are very large in actual size, as shown in Fig. 35. In this illustration is shown the figure of a man which gives an idea of the relative size of the ornament. Other examples of the details used in this building are shown in Figs. 36 and 37. In Fig. 38 is shown a detail of two windows in one of the upper stories of the building. At the sills of the lower windows is shown the method of protecting portions of the ornamental work by means of boarding.

FACE AND ORNAMENTAL BRICKWORK

INTRODUCTION

1. Use of Brick.—Brick is one of the most useful of all building materials as well as one with which highly artistic effects can be obtained. Its use for utilitarian purposes, such as building walls and piers, will be considered in the Section entitled *Common Brickwork*. Its possibilities as a decorative material will be discussed in the following pages.

2. Brick as a Decorative Material.—Brick can be used ornamentally or decoratively in two different ways. One way is by laying it so as to form patterns on the surface of walls and piers by the use of different sizes, colors, and surface textures, also by using mortar of varying color and texture and by using mortar joints of different thicknesses. This method of producing attractive and artistic effects in brickwork will be discussed under the heading of Face Brickwork. An example of artistic face brickwork is shown in Fig. 1.

3. Brick can also be used as relief ornament in the form of string-courses, cornices, brackets, etc., which project beyond the face of the wall, as shown in Figs. 2, 6, and 7. Brickwork of this description will be referred to as Ornamental Brickwork.

4. Combinations of Face and Ornamental Brickwork.—Combinations of these methods of using brick have been employed with charming results, as shown in Fig. 2. This



FIG. 1

building is a dove-cote, or pigeon coop, at the Manoir D'Angot in France and was built in the 16th century. This example illustrates the use of *ornamental brickwork* in the projecting



FIG. 2

cornice as well as of *face brickwork* in the patterned surface of the wall. In this building, small blocks of stone have been used in connection with brick to produce contrast in texture and color in the patterns.

5. At the present day architects and builders have at their disposal a wealth of material in the form of bricks of different sizes, shapes, colors, and textures, as well as tiles of all colors, which afford excellent opportunities for designing walls of artistic excellence. An example of such a wall is given in Fig. 1.

DEFINITIONS

6. As there are a number of terms used in connection with brickwork that will be used frequently in connection with the following descriptions, definitions of these terms are here given.

In referring to the individual bricks, the different faces of the brick will be referred to as follows and as illustrated in Fig. 3.

The **top** is the upper large surface.

The **bottom** is the lower large surface.

The **face** is the long narrow side or edge that shows in the face of the wall.

The **back** is the long narrow side or edge opposite the face.

The **heads** are the small ends of the brick.

A **unit** is one brick or piece of brick used in a pattern or a bond.

A **stretcher** is a brick that is laid on its bottom with its face showing in the face of the wall, or a brick whose length extends in the direction of the wall, as shown in Fig. 4 at *a*.

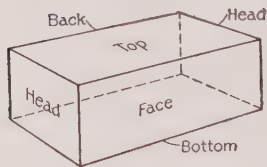


FIG. 3

A **header** is a brick laid on its bottom with the head showing in the face of the wall, as at *b*.

A **bull header** is a brick laid on its face or back and showing a head in the face of the wall, as at *c*.

A **course** of brick is one horizontal row of bricks, as at *e*.

A **stretcher course** is one row of *stretchers*, as at *d*.

A **header course** is one row of *headers*, as at *e*.

A **rowlock**, or **rollock**, **course**, is a row of *rowlocks*, or *bull headers*, as shown at *f*

A **soldier course** is a row of bricks with the faces laid vertically, as shown at *g*.

A **string-course** is a horizontal course continued across the face of a building. It generally projects and may be flat, molded, or carved.

A **herring-bone pattern**, shown at *h*, consists of bricks laid diagonally in opposite directions.

Bond is the arrangement of the bricks in the wall by which the wall is tied, or bonded, together. This bonding is accomplished by lapping each brick over two or more bricks below it.

Face bond is a bond, or pattern, which shows on the face of the wall but is not generally carried through the entire thick-

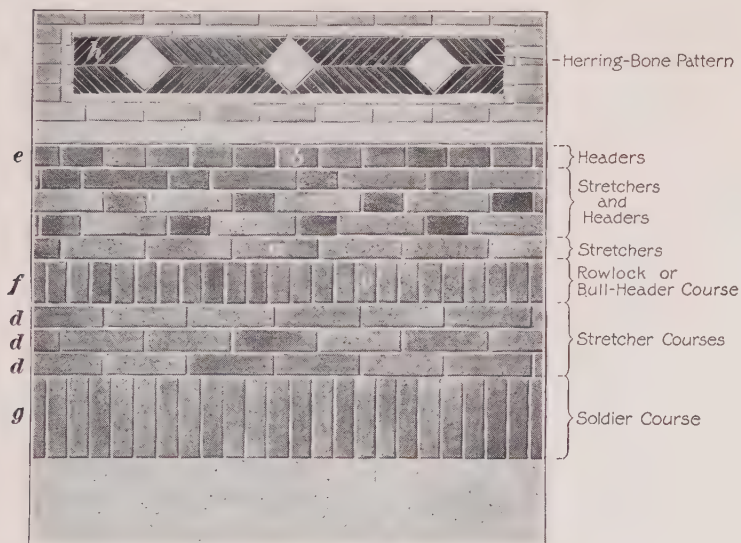


FIG. 4

ness of the wall. The substantial body of the wall may be built in some strong bond that is economical to build, while the face of the wall may be finished in a more elaborate and totally different bond. This ornamental facing of brick must be securely fastened to the wall back of it, upon which it depends for support. The substantial wall to which the facing is attached, or bonded, is often referred to as the **backing**.

The **brick field** is the brick surface of the wall.

Breaking joints is the arrangement of the joints of the brickwork so that the vertical joints in one course shall not come directly above the vertical joints in the course below.

A **blind joint** is a joint between two bricks that is made as thin and inconspicuous as possible so as scarcely to be noticeable.

BRIEF HISTORY OF BRICKWORK

7. Brick architecture has naturally developed in countries or parts of countries where there was an abundance of clay from which bricks could be made, and where there was a scarcity of wood and stone. Thus, in ancient Babylonia, most of the building of importance was done with clay products such as brick. Some of these bricks were merely dried in the sun,

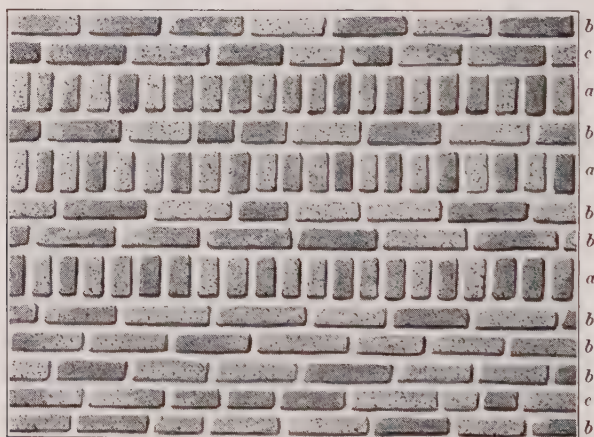


FIG. 5

and are known as *sun-dried* bricks, while some of them were baked in kilns as is done at the present day. A few examples of typical brickwork of various countries, both ancient and modern, will now be described and shown.

8. **Egypt.**—Brickwork found in ancient Egyptian tombs is illustrated in Fig. 5, which shows an example from the tomb

of Mersekha, built about the year 2900 B. C. This brickwork shows a pattern, or bond, which consists of rows of headers *a* separated by rows of stretchers *b*. The headers are bull

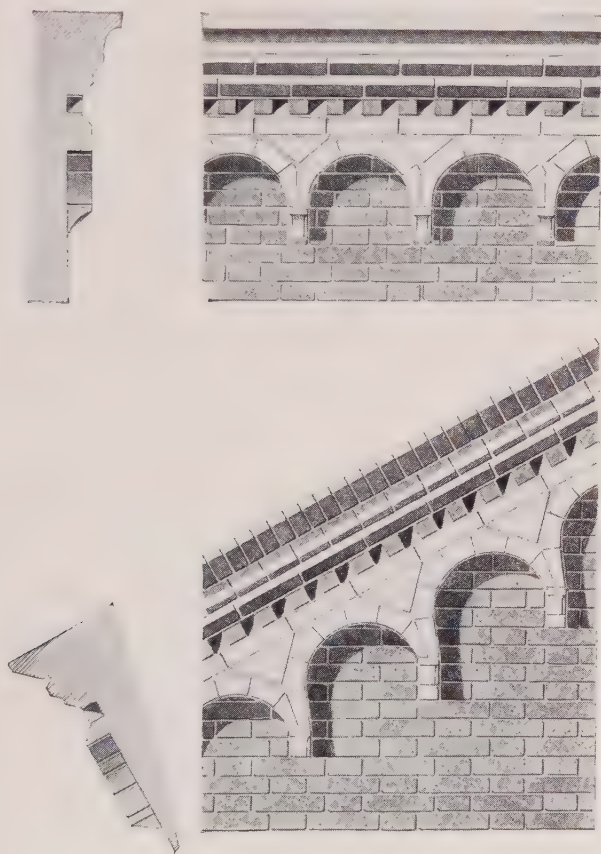


FIG. 6

headers. The bricks are roughly molded and irregular in size. Headers are introduced occasionally in the rows of stretchers, as shown at *c*. A number of the well-known Egyptian pyramids were built of brick.

9. Ancient Rome.—The Romans used brick extensively. The bricks themselves were always flat, varying from $\frac{1}{2}$ inch

to 2 inches in thickness. In the Baths of Titus, erected about 80 A. D., the bricks were about 18 inches by 6 inches by 2 inches in size. Bricks found in remains of Roman structures in England are dark red and light red in color, these colors being used together in the walls. These bricks were laid with wide mortar

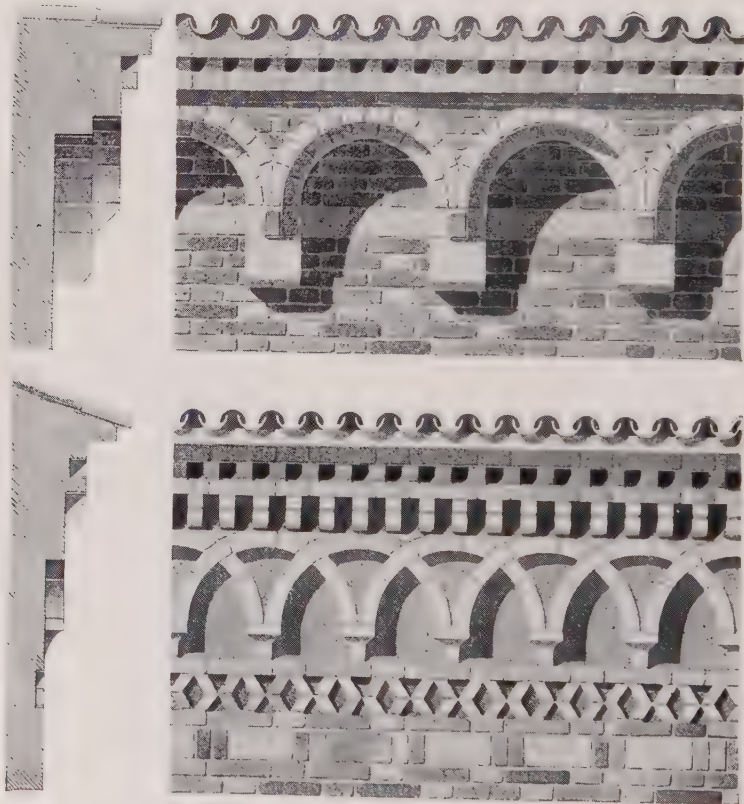


FIG. 7

joints, and the mortar used was generally composed of lime mixed with broken tiles, sand, and gravel more or less coarse in size.

Excellent examples of Roman brickwork have been found in England. At Caster, an ancient Roman camp, a fine example of herring-bone masonry was found. Another example exists in St. Botolph's Priory near Colchester.



FIG. 8

10. Italy. — In Italy during the Middle Ages, especially in the cities of the North, brick architecture reached great perfection in its application to churches and civic buildings. Brick was used in connection with terra cotta and stone, and ornamental brickwork of the highest artistic character was used in the cornices of Italian buildings. Examples of these cornices are shown in Figs. 6 and 7. Other examples of Italian brickwork are: Baptistry of St. Stefano, 4th century; St. Agata in Ravenna, 5th century; Cathedral, Cremona, 12th century; Broletto (Town Hall), Brescia, 13th century; San Pietro Ciel D'Oro, Pavia, 13th-15th centuries.

11. Persia. — It was in the 16th century that Persian brickwork reached that degree of excel-

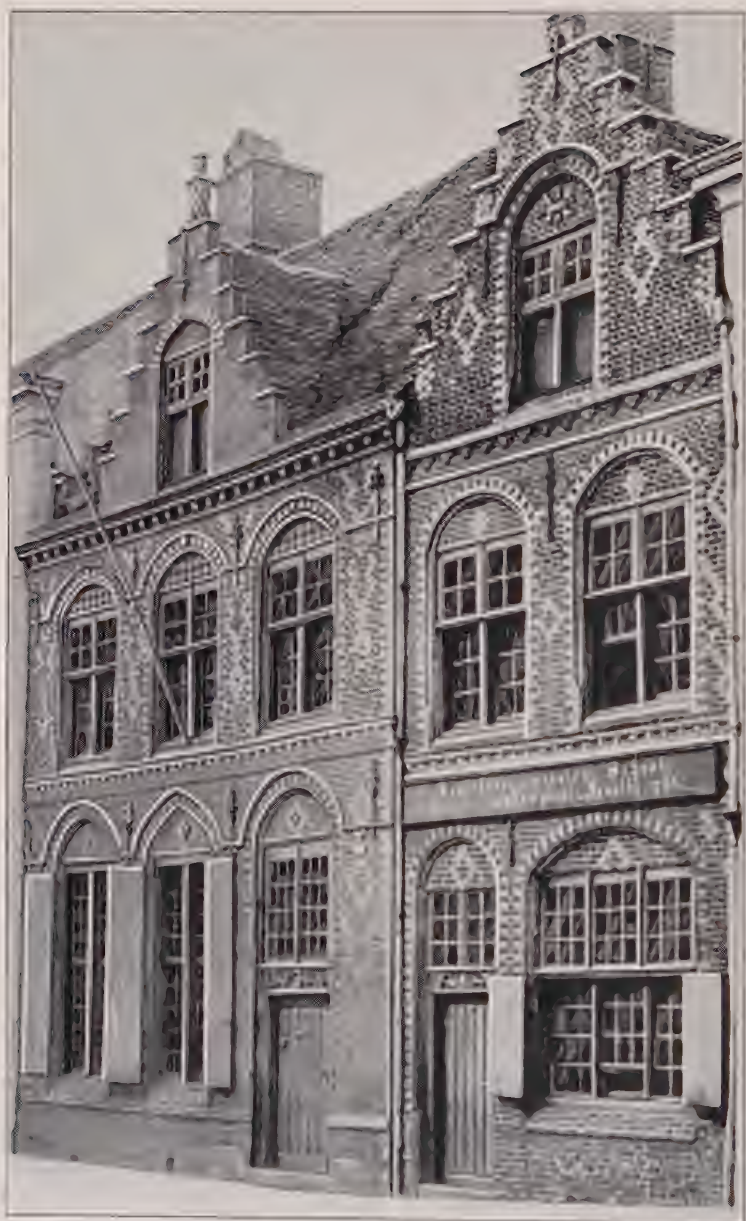


FIG. 9

lency which characterizes so many Persian mosques and mausoleums as masterpieces of the brickbuilder's art and ingenuity. Notwithstanding that brick architecture had been practiced in Persia from the 7th century, it was in the early part of the 16th century that buildings were built that are notable for their workmanship, color, and design. At Bostam, Ispahan, Tebriz, and Ardebil, the mosques and minarets are monuments of the possibilities of brick as a means of decoration. An example of this work is given in Fig. 8. The building shown is a minaret, or prayer tower, connected with the mosque of Tschihil Sutun in Dangan, Persia, and was built in the 16th century.

12. Netherlands.—During the 14th and 15th centuries, the brickbuilders of the Netherlands were not only erecting their homes and public buildings of brick, but were also instructing their neighbors, the English, in the use of brickwork. Their buildings with the quaint *stepped* gables possess great individuality and charm. In Fig. 9 are shown two excellent buildings which were built in Ypres, Belgium. These buildings show the delicacy and refinement with which brick was employed, and also illustrate the formation of patterns by the use of brick of different colors. Molded brick have also been used around the windows and in the string-courses.

Notable examples of brickwork are given in the following list of buildings:

Church of St. Martins, Ypres, Belgium. . . .	14th century
City Gates, Haarlem, Holland.	15th century
Tournal House, Holland.	15th century
St. Jean Hospital, Hoorn, Holland.	16th century
Convent des Celestines, Tournal, Holland. .	16th century

13. England.—The earliest brick building existing in England is Little Wenham Hall in Lincolnshire, which was built in 1260. By the year 1300, brickwork was in general use in England. The great manor houses of England were erected in the 15th and 16th centuries, as shown by the following list of such buildings:

12 FACE AND ORNAMENTAL BRICKWORK

	ERECTED
Hurstmanceaux Castle	1440
Tattershall Castle	1440
Rye House (Hertfordshire)	1440
Lollard's Tower (Lambeth Palace)	1454
Layr Marney Towers	1500
Sutton Place, Guilford	1523
Compton Wynyates	16th century
East Barsham Manor	late 16th century

A portion of the last-mentioned building is shown in Fig. 10.



FIG. 10

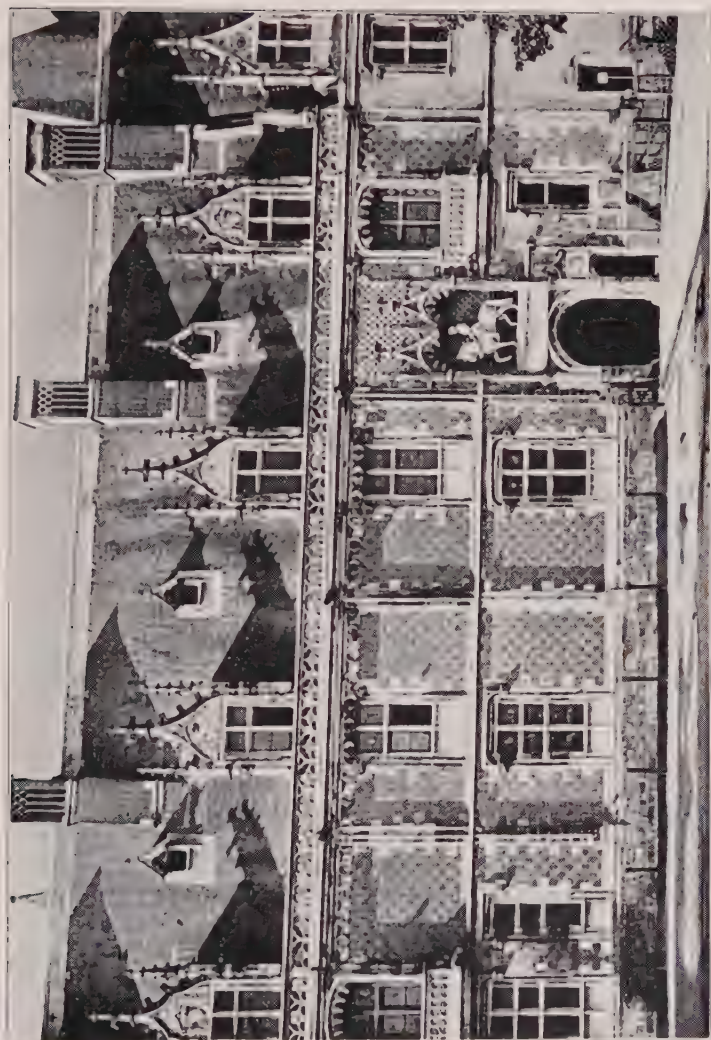


FIG. 11

14 FACE AND ORNAMENTAL BRICKWORK

It was undoubtedly from the Flemish brickbuilders of the Netherlands that the English received the incentive to erect the series of magnificent brick buildings that mark the progress of the history of England.

14. France.—The French people used brick with excellent taste but generally used it for wall treatments in which the brickwork was framed by stone. This treatment is shown in the Louis XIII wing of the Château of Blois illustrated in Fig. 11. The brick surface has a crisscross pattern formed by bricks that are lighter in color than the others. A particularly charming example of French brickwork is shown in Fig. 2, which is the dove-cote at the Manoir D'Angot of the 16th century. Other noteworthy examples of brick architecture are the Château de Martainville of the 15th century at Epreville; the Manoir D'Angot itself, and a pigeon house at Boos.

15. America.—In America, during the Colonial period of its history, our architects and builders developed the Colonial Style of Architecture, which was an offshoot of the Georgian style in England. Brick was imported from England and used with considerable taste in some of the colonial houses in the southern colonies, such as Maryland and Virginia. A decline in architectural taste occurred during a great part of the 19th century but a revival, or renaissance, of good taste has been experienced in recent years which gives promise of most satisfactory results.

Many excellent buildings by such architects as H. H. Richardson, McKim, Mead, and White, and by prominent living architects, are fine examples of brickwork. Designers of the present day have the best possible opportunities for producing fine brickwork, as the manufacturers are now making superior grades of brick which offer great varieties of color, size, and texture as well as durability.

FACE BRICKWORK

DESCRIPTION OF FACE BRICK

BRICK SHAPES AND SIZES

16. The sizes of brick units varied in past ages, according to the locality in which they were produced and the use to which they were to be put, just as they do today. In an ancient Sargonic arch, made about the year 4000 B. C., the bricks measure 12 inches by $2\frac{1}{2}$ inches by 6 inches. Ancient Babylonian brick measured 12 inches by $5\frac{7}{8}$ inches by $2\frac{1}{4}$ inches. Other Babylonian bricks measured $8\frac{5}{8}$ inches by 2 inches by $4\frac{7}{8}$ inches, which are similar in size to bricks made at the present time.

The Roman bricks, as has been stated, were made 18 inches by 6 inches by 2 inches in size.

17. Brick Sizes as Used in the United States.—The standard sizes of brick in the United States are those adopted by the National Brickmakers' Association. For common brick the standard size is $8\frac{1}{4}$ in. $\times$ 4 in. $\times$ $2\frac{1}{4}$ in.; for face brick, $8\frac{3}{8}$ in. $\times$ $4\frac{1}{8}$ in. $\times$ $2\frac{1}{4}$ in.

The brick manufacturers, in making standard brick, only approximate these sizes, as it is impossible to regulate absolutely the amount of shrinkage that will take place between the time the brick is molded and the time it is thoroughly burned. Differences in size are almost invariably found in the same shipment of brick.

It is customary, especially when a fine joint is to be used, to sort out these face brick and place all the bricks of the same size in one pile and those of other sizes in other piles. These different sizes are used in different portions of the wall so that the difference in size is not noticeable.

In some cases the manufacturers make bricks that vary considerably in size from the standard brick. It is therefore advisable, before laying out the drawings for the front of a building that is to be faced with face brick, to obtain by actual measurement the exact size of the bricks that it is desired to use, so as to make the openings in the wall, especially the heights, of sizes that are multiples of the brick size. It is also necessary to know the exact size of the bricks to be used when stone or terra cotta are used in connection with the face brick, to make the heights of the stone or terra-cotta courses equal in height to a given number of brick courses so that the horizontal joints shall coincide.

18. Sizes of Standardized Brick.—There are a number of other standardized sizes of face brick, the names and the approximate sizes of which are given herewith. These sizes are obtained from catalogs of prominent manufacturers and show the variations in sizes which are sold under the same name.

NAMES AND SIZES OF FACE BRICK

NAMES OF BRICK	APPROXIMATE SIZE	
	INCHES	
Real Roman	{	$18 \times 2 \times 6$
		$17\frac{1}{2} \times 1\frac{1}{2} \times 5\frac{1}{2}$
		$18 \times 1\frac{1}{2} \times 6$
Norman	{	$12 \times 2\frac{1}{2} \times 4$
		$11\frac{7}{8} \times 2\frac{1}{4} \times 4$
Roman	{	$12 \times 1\frac{1}{2} \times 4$
		$11\frac{1}{2} \times 1\frac{3}{4} \times 4$
		$11\frac{5}{8} \times 1\frac{5}{8} \times 3\frac{7}{8}$
English	{	$8\frac{7}{8} \times 2\frac{7}{8} \times 4\frac{3}{8}$
		$7\frac{3}{4} \times 2\frac{1}{2} \times 3\frac{1}{2}$
Standard	{	$*8\frac{3}{8} \times 2\frac{1}{4} \times 4\frac{1}{8}$
		$8 \times 2\frac{1}{4} \times 3\frac{3}{4}$
		$8\frac{1}{4} \times 2\frac{1}{4} \times 4$
		$8\frac{1}{8} \times 2\frac{3}{8} \times 4$
Split		$8 \times 1\frac{1}{8} \times 4$
Pony		$6 \times 1 \times 2\frac{3}{4}$

* Standard recommended by National Brickmakers' Association.

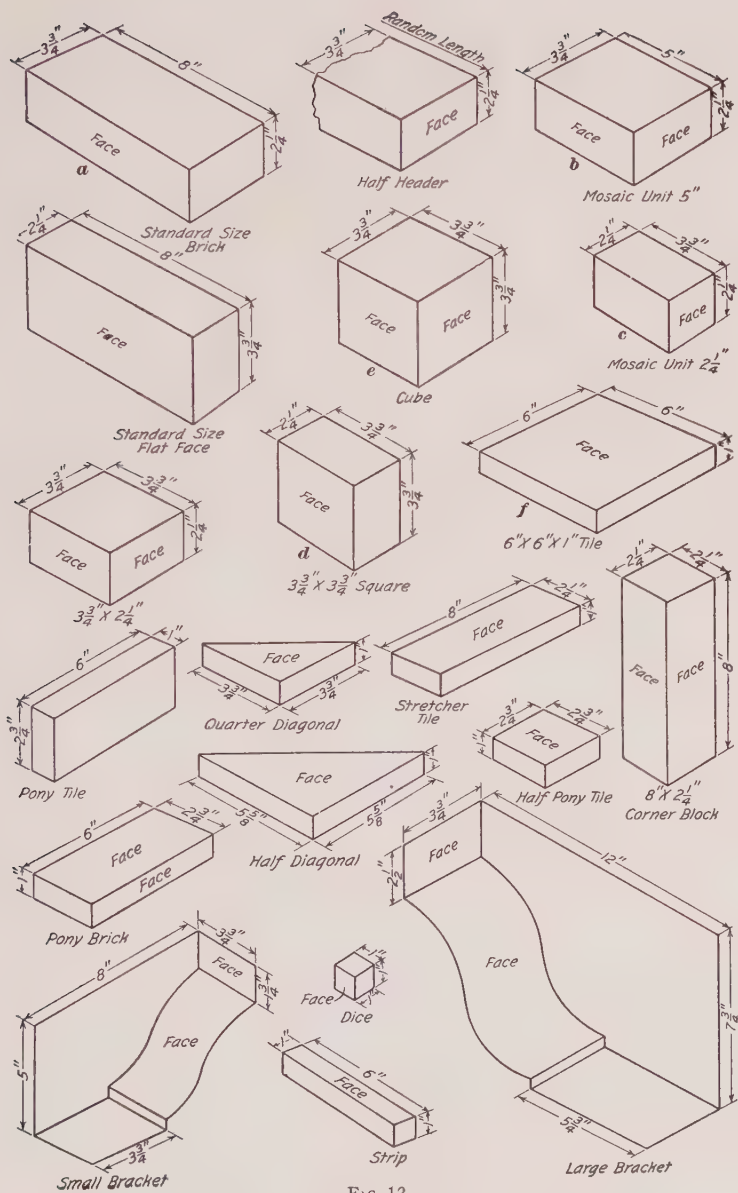


FIG. 12

19. Special Shapes.—Besides these standardized sizes and shapes, there are many special shapes made for use in pattern work. Some of these special shapes are shown in Fig. 12. The sizes of these units are marked in the illustration.

By using the standard-sized brick *a* with the 5-inch unit *b* and the $2\frac{1}{4}$ -inch unit *c*, reproductions of the interesting Persian pattern work such as shown in Fig. 59 can be made.

The square piece *d*, measuring $3\frac{3}{4}$ inches by $3\frac{3}{4}$ inches, is used in turning the corner of a border of bull-headers, or rollocks, as shown at *a* in the panel in Fig. 60. The cube *e*, Fig. 12, is used in turning the projecting corner in a course of rollocks, as shown in the upper corners of the brick flower boxes in Fig. 49. The square brick or tile *f*, Fig. 12, 6 in. $\times$ 6 in. $\times$ 1 in. in size, is used in positions such as shown in the ornamental bands at the tops of the bay windows in Fig. 63.

These special shapes save the mason a great deal of cutting and insure better results in laying out the work; also, they can be used in different colors than those used in the field so as to produce contrasts both in form and color.

20. Tile.—Tile are made of clay similar to that of which face brick are made and have, to a large extent, the same texture and coloring. Enameled and decorated tile are made in numerous shapes, colors, and designs. Patterns made of tiles are often used very effectively in connection with brickwork.

These tile are manufactured of the sizes and surfaces given in the accompanying list:

SIZES AND SURFACES OF TILE		
SIZE.	INCHES	SURFACE
12 $\times$ 12 $\times$ 1		Smooth
9 $\times$ 9 $\times$ 1		Smooth
9 $\times$ 6 $\times$ 1		Smooth
8 $\times$ 8 $\times$ 2		Rough and semismooth
6 $\times$ 6 $\times$ 1		Rough, smooth, and semismooth
6 $\times$ $2\frac{3}{4}$ $\times$ 1		Rough and semismooth
4 $\times$ 4 $\times$ 1		Smooth
$2\frac{3}{4}$ $\times$ $2\frac{3}{4}$ $\times$ 1		Rough and semismooth
Half diagonal of a 6" $\times$ 6"		Rough and semismooth
Quarter diagonal of a 6" $\times$ 6"	..	Rough and semismooth

The rough tile has a decidedly rough texture on its face and is used for the floors of porches and terrace walks as well as for wall decoration in connection with rough-textured brick.

BRICK TEXTURES

21. Rough Textures.—A rough texture is commonly produced by mixing a coarse material such as grit or small



FIG. 13

pebbles with the clay, or by cutting the brick with wires when molding it, or by both methods. Fig. 13 shows a brick that is artificially roughened by the introduction of grit and pebbles in the clay. Another example of a brick surface containing pebbles is shown in Fig. 14.

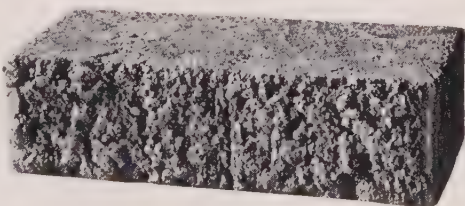


FIG. 14

The surfaces are also roughened by cutting the brick, when molding it, with wires, which drag and tear the soft clay surface, as shown in Figs. 15 and 16. Such brick is called *wire-*

cut brick. When the wire cuts the brick from one end to the other a surface is produced such as is shown in Fig. 15. This

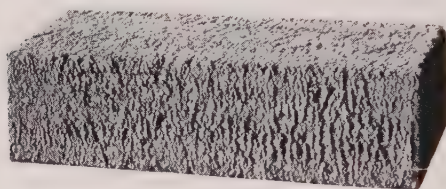


FIG. 15

brick is called an *end-cut* brick. When the wire is drawn from one long edge to the other, a surface like that shown in Fig. 16 is produced. This brick is a *side-cut* brick. The

brick shown in Fig. 13 has been roughened not only by the use of a coarse ingredient in the clay but by a subsequent scratching which produced the vertical marks shown on some of the bricks. Figs. 15 and 16 show a brick with a medium-rough surface.

An example of a rough brick surface, which is due to irregularity in burning during the processes of manufacture, is shown in *clinker* brick which has been cracked and twisted out of shape by the flames in the kiln. This brick, which in the past was generally sent to the rubbish heap, when used with taste and skill forms an artistic wall surface that possesses character and interest. A portion of a wall built of clinker brick is shown in Fig. 17.

22. Smooth Textures.—A smooth brick may be either a *pressed* brick, which is pressed by machinery into an accurate shape with edges absolutely true, or a *wire-cut* brick, which has the largest surfaces cut by the wires of the brick-cutting machine, while the other faces are all perfectly smooth. The edges of a wire-cut smooth brick are not as true as those of a pressed brick and consequently the brick when set has not that mechanical appearance which is characteristic

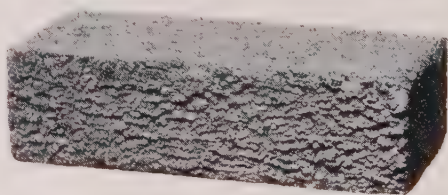


FIG. 16

of pressed-brick work. An example of a wall laid up with a smooth-textured brick is shown in Fig. 18.

23. Effect of Texture.—A wall built of bricks that are perfect in shape, absolutely smooth, uniform in color, and laid up with fine even joints, is not only very expensive to build but is very mechanical and inartistic in appearance. This fact is appreciated by architects and designers, and the best modern brickwork is constructed with brick which has more or less roughness of surface and variety of color, and of which the individual bricks are not mechanically perfect in form. With



FIG. 17

brick of this description, properly selected and laid, a wall can be laid that will have character, brilliancy, and interest. Such a wall will not appear hard and set; the color will not be monotonous, and the surface having some texture will give a play of light and shadow that will enliven the appearance of the wall and add brilliancy to the color.

By using some of the rougher-textured brick, new brickwork can be built so as to have a great deal of the charm of ancient work which is so much admired. One of the greatest charms

of the brickwork of the old colonial houses lies in the slightly rough texture and the soft color tones of the brick units.

24. At a distance from the building, the particular texture of the brick units is lost, but the effect of the rougher textures

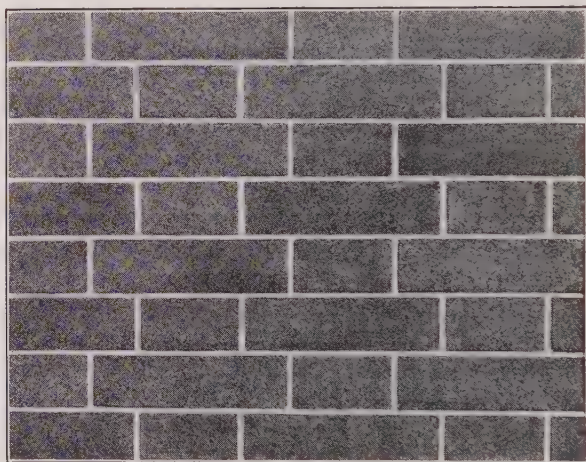


FIG. 18

is to soften the color of the mass of the brickwork and to do away with the glare which often occurs when the brick units are very smooth in texture.

25. Modern face bricks are generally burned so that they are almost vitrified and will not absorb moisture. Dust from the atmosphere which may lodge on the rough surface of the brick will therefore not be absorbed but will be washed off by rain, thus leaving the color of the brick fresh and clear.

BRICK COLORS

26. Causes and Varieties of Brick Colors.—Bricks in the United States and in Europe are naturally red in color, although, in some parts of the United States, clay is found that produces a yellow-colored brick. The bricks made in China and Japan are generally of a slaty-blue color.



By courtesy of Fiske & Co., Inc.

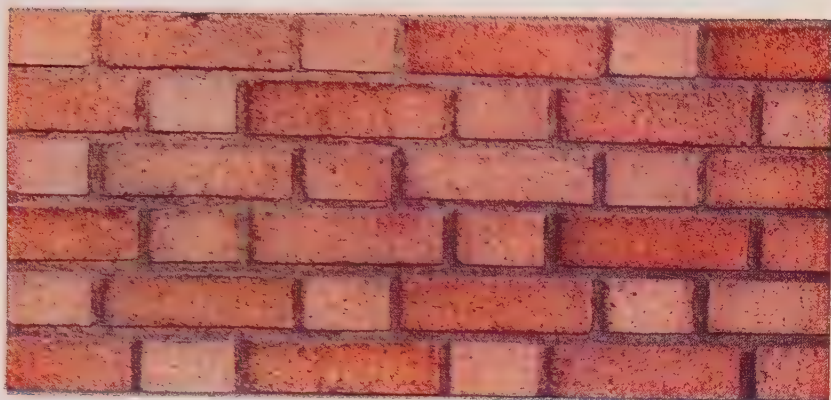
FIG. 19



By courtesy of Fiske & Co., Inc.

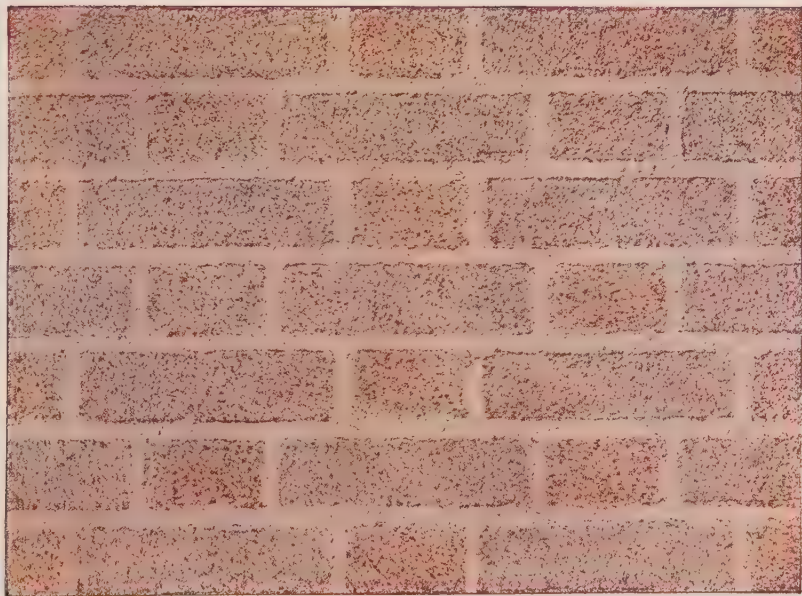
FIG. 20

L. E. T. 31F-1832



By courtesy of Fiske & Co., Inc.

FIG. 21



By courtesy of Hydraulic-Press Brick Co.

FIG. 22



By courtesy of Hydraulic-Press Brick Co.

FIG. 23



By courtesy of Hydraulic-Press Brick Co.

FIG. 24

The presence of iron, magnesia, lime, and other materials in the clay causes the different colorings in the finished brick. Iron in the clay will produce such colors in the brick as light yellow, orange, red, dark blue, and purple, according to the amount of iron present in the clay and the heat at which it is burned. Magnesia gives a brown color; magnesia and iron together, a yellow color; lime and iron together, a drab color.

Different clays contain these elements naturally, and by skillfully mixing selected clays, bricks can be made in a large variety of colors without the use of artificial coloring materials.

The degree of heat at which the bricks are burned has a great effect upon the color of the brick. This is well illustrated in the case of common bricks, which are taken from the old-style kiln with colors varying from a light salmon color to dark blue, according to the amount of heat to which they have been subjected.

The colors in which modern bricks are made are *reds*, varying from light pink to deep red; *buffs*, varying from a light cream color to deep, rich browns; *browns*, which vary from a light brown to a dark brown. There are also blues, purples, greens, and various fancy colors. Examples of some of these colors are shown in the colored illustrations in this Section.

There are generally variations in the face color of the same brick which give an interesting appearance to the individual bricks and also to the brick field. Such brick is shown in Figs. 19, 20, 21, and 22.

The bricks sometimes have iron spots on the surface, as shown in Figs. 23 and 38, or mottles, as shown in Figs. 24 and 29. The surface is sometimes glazed. In short, there is a great variety of texture and color from which the architect may choose, and the success of the choice will depend upon his taste and experience.

27. Judging Effects.—The color or texture of the completed wall can never be correctly judged from the color or texture of a single brick or even from a number of bricks laid up, as the atmosphere and the distance of the wall surface from the eye greatly affect the appearance of the brick. The

best way to judge the effect of a given brick in a building is to see a building built of the same kind of brick, which often can be done.

When a wall of the desired brick cannot be seen, a small sample wall of the chosen brick and mortar is laid up with a certain bond and width of joint. If this sample wall is satisfactory, the combination is adopted and used. If, however, the sample does not meet with approval, other bricks, mortar, joints, and bonds are tried by building small sections of wall until a satisfactory combination is discovered.

In the show rooms of brick dealers, a variety of such sample walls can generally be seen, which will assist the architect and the client in selecting a satisfactory combination.

MOLDED BRICK

28. Ornamental brickwork may be formed of plain brick which is built so as to project and form cornices and

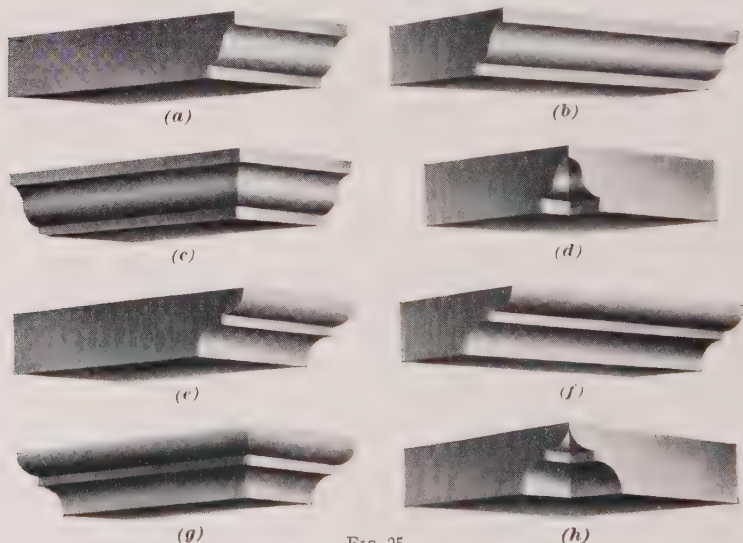


FIG. 25

string-courses in the manner shown in Figs. 2, 6, and 7, or by the use of bricks which are molded into various shapes.

These bricks are made in a large variety of shapes so that many architectural details such as cornices, string-courses, panels, window sills, columns, and pilasters can be made of them.

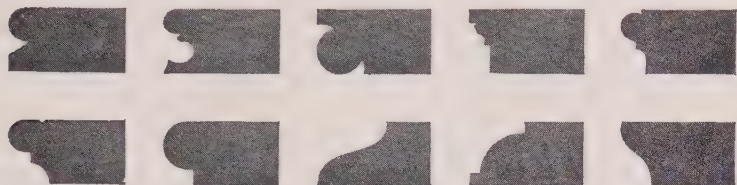


FIG. 26

The projection of molded brick details must necessarily be small, but several courses of brick can be projected over each other so as to produce a satisfactory total projection in the entire cornice.

The units in which molded brick is made are of such a size that they can readily be laid up with standard face brick and the horizontal joints can be maintained at each course or two.

Some of the more common and useful shapes that are made in molded brick are shown in Fig. 25. In (a) is shown a mold-



FIG. 27

ing known as a *cyma recta*, or crown, molding. These bricks are generally made in four forms to fit them for use in a string-course. A header for this molding is shown in (a); in (b) is a stretcher, in (c) a projecting corner, and in (d) a sunk corner,

In *e*, *f*, *g*, and *h* are shown the four molded bricks required for another form of crown molding, called a *cyma reversa*.

Several profiles of molded brick commonly used are given in Fig. 26. The necessary headers, stretchers, and corners are also made for these moldings.

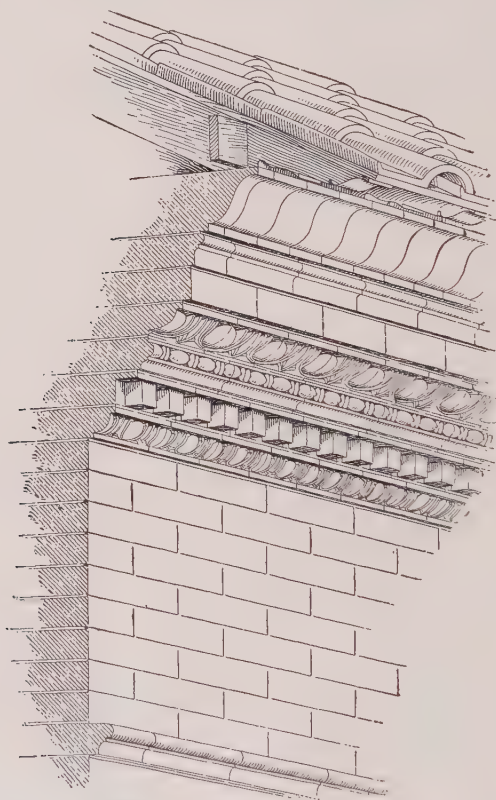
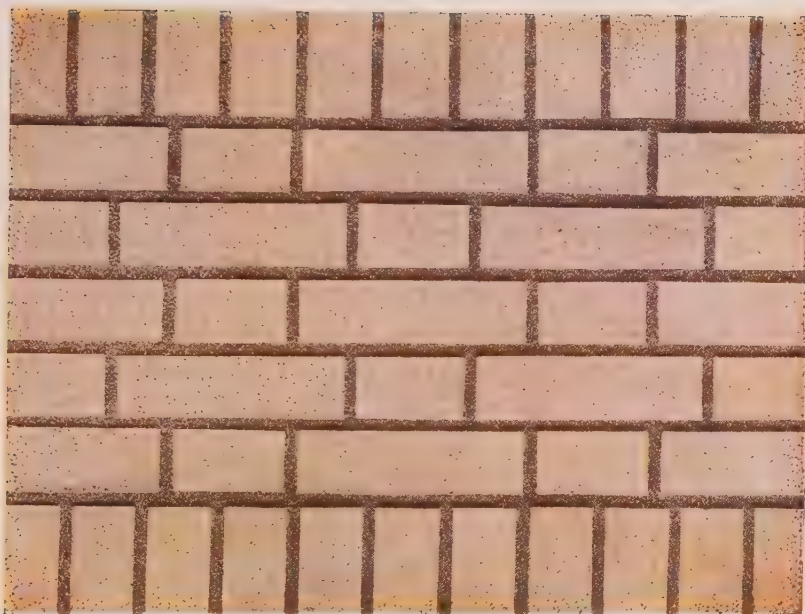


FIG. 28

Ornamental band courses having ornament in relief or projection are shown in Fig. 27.

29. Molded brick are generally made with a smooth finish and are used to the best advantage with smooth-faced brick. They cannot very well be used together with the rough-textured brick that are so popular at the present day.



By courtesy of Hydraulic-Press Brick Co.

I L T 31F—1832

FIG. 29

Molded brick of rough texture are, however, sometimes made of the same color and texture as the brick used in the brick field; an example of such brick is shown in the moldings over the door and window in Fig. 49.

30. Molded Brick Cornice.—A cornice composed of molded brick, together with plain face brick, is shown in Fig. 28. As before stated, the projection of each course must be small, and the total projection cannot be so great as that of a cornice made of stone, terra cotta, or wood.

MORTAR AND MORTAR JOINTS

31. Effect of Mortar and Mortar Joints.—The mortar joint and the mortar are essential factors in the appearance of finished brickwork. In fact they are almost as important as the color and the texture of the brick in their effect upon the appearance of the wall. Where a very thin joint is used, as in Figs. 23 and 24, the principal effect is caused by the *color* of the mortar.

The color of the mortar may be in contrast with the color of the brick, as in Fig. 29, thus forming a network of contrasting color over the entire surface of the wall, or it may be similar in color to the brick itself, as in Fig. 24, in which case the wall will have a uniform, and possibly a monotonous, color effect.

The wider the joints the greater will be the effect of the color of the mortar upon the wall. In an extreme case, such as shown in Fig. 19, where the bricks used are 18 in. $\times$ 2 in. on the face and the mortar joints are 1 inch in width, the areas of the brick and the mortar showing in the face of the wall are as 2 is to 1, or, the area of the mortar in the face of the wall is one-third of the entire area of the wall. It will readily be seen that in such a case the color of the mortar would be extremely important.

32. Whether the mortar in the joints is flush with the surface of the bricks or is slightly recessed also makes a great difference in the appearance of the wall. If the mortar is kept

flush with the surface of the bricks, as shown in Figs. 18 and 19, the effect of the joint depends entirely upon the texture and color of the mortar. When, however, the joints are recessed, or *raked*, each brick casts a small shadow on the mortar joint, making a dark line below and on one side of each brick, which makes the bricks stand out separately and also emphasizes the joints, as shown in Figs. 13 and 20.

33. The mortar may have a smooth or a rough texture. In Figs. 24 and 29 the mortar shows a smooth texture, in Figs. 13 and 20 a rough texture. The rough-textured mortar has a brilliancy due to the alternation of light and shade, and is generally used with a rough-textured brick.

34. Composition of Mortar for Face Brick.—For fine joints and for smooth-faced brick, a mortar made of fine sand, cement, and lime is satisfactory; and mortar colors may be added to give the mortar the desired tone or color. This mortar, however, is unsatisfactory for a joint $\frac{1}{2}$ inch or more in width, as it is too soft and pasty and would squeeze out between the bricks while they are being laid.

Practical experience has demonstrated that, with the proper kind of mortar, brick can be laid with a wide rough joint even more rapidly than with a narrow one.

35. Materials Used for Making Mortar.—Mortar for joints over $\frac{3}{8}$ inch in width should contain a liberal proportion of fine pebbles, $\frac{1}{4}$ inch or less in diameter, known to the building trade as *grit*, in addition to coarse sand, cement, and a small amount of lime putty or hydrated lime, and coloring matter if desired.

36. Grit.—Grit consists of small pebbles $\frac{1}{4}$ inch or less in diameter, and should be screened so as to remove all sand. This material gives a characteristic texture to the mortar, as shown in the joints in Fig. 13. It also gives a body to the mortar which enables it to stand up under the brick until the cement sets.

37. Sand.—Ordinary bank or pit sand is satisfactory for dark-colored joints, but where white or light-colored mortar is required, either white sand or coarsely ground marble or limestone is used. For very fine white joints pulverized marble, called *marble dust*, is used. Sand from sea beaches is not a desirable sand to use for mortar unless it has been thoroughly washed. If it is not washed the salt is apt to appear on the face of the brickwork in the form of efflorescence.

38. Cement.—The best cement to use for all brickwork is standard Portland cement. For white mortar, however, a white Portland cement, which is made from white clay and limestone and possesses the qualifications of a standard Portland cement, is preferable.

39. Lime.—*Lime putty* adds to the whiteness of the mortar and also makes the mortar work more easily under the trowel. The lime should be well slaked and strained and allowed to stand for several days before it is used.

Hydrated lime is lime artificially slaked, and is sold in the form of a very fine powder. Under most conditions hydrated lime may be used instead of lime putty. It has the advantage that it can be used immediately, whereas lime putty requires several days for preparation.

40. Coloring Materials.—Most of the mortar colors employed to color the mortar used in laying and pointing face brickwork consist of mineral pigments, and are sold either as a dry powder or in the form of pulp or paste. The pulp colors seem to mix better with the mortar than the dry colors and are therefore preferable for the better class of work. Mortar colors, whether dry or in paste form, should never be mixed with lime until the lime has been slaked for at least 24 hours. The mortar color should in any case be thoroughly mixed with the mortar, and exactly the same amount of color used for a given quantity of mortar. If this is not done there will be variations in the color of the finished mortar joints which may not be desirable.

The color of mortar appears to be much darker when the mortar is wet than when it is dry. It is therefore advisable to mix a sample of the mortar containing a measured quantity of mortar color and try it out on a small portion of the wall. This, when dried out, will show the true color of the mortar in connection with the brick. If the first experiment is not satisfactory, other mixtures of mortar can be tried until a good color is obtained. The proper proportion of mortar color having thus been determined, all mortar that is afterwards prepared should be mixed in exactly the same proportions.

41. Suggestions for Coloring Mortar.—The following are useful suggestions as to the color of mortar to be used with different colored brick.

With brick of varying shades of *red*, a cream-gray mortar, as shown in Figs. 19 and 20, is effective. Where a darker effect is desired a dark reddish brown mortar may be used.

With *gray* brick, light-gray mortar, such as shown in Fig. 24, is good. Where a thicker joint is used, a raked joint is very effective. For a darker effect, mortar of a dark gray or a dark brown, such as shown in Fig. 29, is a good color to use.

For brick of golden or buff shades, a cream-gray or warm-gray mortar is effective.

42. Formulas for Mixing Mortar.—The following formulas for mortars are the result of careful experiments and will make excellent mortars of the colors named. The term *part* as here used refers to any unit that may be used as a measuring unit. For small batches of mortar a mason's bucket of 14 or 16 quarts capacity may be used and each bucketful considered as a part. For large quantities of mortar a tight barrel, such as a Portland cement barrel, may be used as a measure of one part. It is very important that exactly the same proportions of the ingredients be used in all the batches or else each batch will show a different color in the wall, which may be very undesirable.

One of the small batches made with a bucket as the unit, mixed according to one of the following formulas, should be enough mortar to lay 100 bricks.

FORMULA I. LIGHT-GRAY MORTAR: PARTS

Quarter-inch grit	2
Coarse sand	5
Portland cement	1
Hydrated lime	$\frac{1}{2}$

FORMULA II. CREAM-GRAY MORTAR:

Quarter-inch grit	2
Coarse sand	5
Portland cement	1
Hydrated lime	$\frac{1}{2}$
Yellow powder mortar color.....	$\frac{1}{6}$

FORMULA III. DARK-GRAY MORTAR:

Quarter-inch grit	2
Coarse sand	5
Portland cement	1
Hydrated lime	$\frac{1}{2}$
Yellow powder mortar color.....	$\frac{1}{12}$
Black paste mortar color.....	$\frac{1}{16}$

FORMULA IV. DARK-BROWN MORTAR:

Quarter-inch grit	2
Coarse sand	5
Portland cement	1
Hydrated lime	$\frac{1}{2}$
Yellow powder mortar color.....	$\frac{1}{3}$
Brown paste mortar color.....	$\frac{1}{3}$
Black paste mortar color.....	$\frac{1}{50}$

FORMULA V. LIGHT-GRAY MORTAR: (For a small batch)

Quarter-inch grit	2 buckets
Coarse sand	5 buckets
Atlas cement	1 bucket
Hydrated lime	$\frac{1}{2}$ bucket
Yellow powder mortar color.....	1 pint

43. Amount of Mortar Required.—The amount of mortar required for laying face brick will, of course, depend upon the thickness of the joint used. For joints $\frac{1}{4}$ inch to $\frac{3}{8}$ inch thick between standard-sized brick, about .4 to .6 cubic yard of mortar will be required for laying 1,000 brick. For joints

$\frac{1}{2}$ inch to $\frac{5}{8}$ inch thick about .8 to .9 cubic yard, and for joints $\frac{3}{4}$ inch to 1 inch thick about 1.2 to 1.6 cubic yards, will be needed to lay 1,000 brick. One barrel of cement and 3 barrels of sand will make about 12 cubic feet, or .44 cubic yard, of mortar.

44. Finish of Joints.—It is always best to finish the joints of the face brickwork as the work progresses rather than

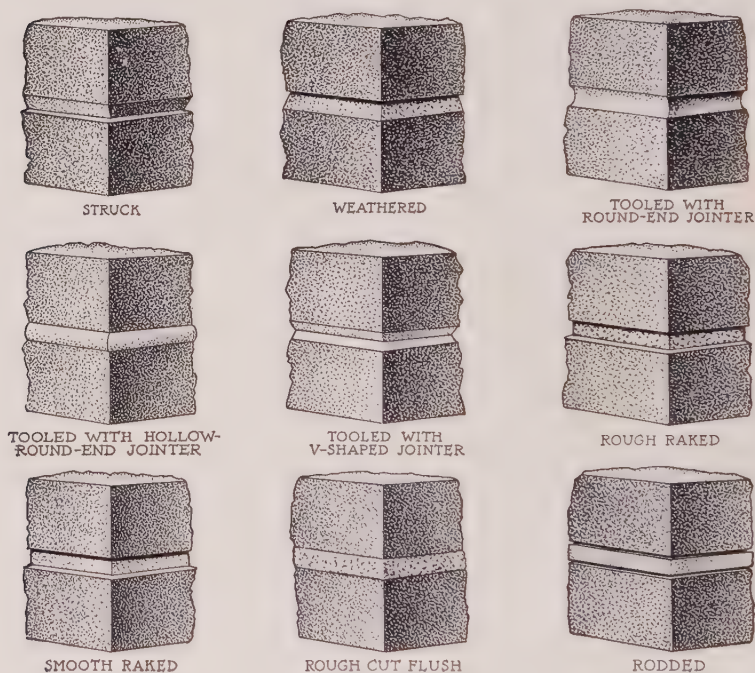


FIG. 30

to rake out the joints and point them after the wall has been built. There are several ways of finishing the joints, which have become standard, all of which have some practical or artistic merit. They are illustrated in Fig. 30.

A **struck joint** is one that is made by drawing the point of the trowel along the joint and smoothing out the mortar so that the upper edge of the joint is flush with the brick while the lower edge of the joint is slightly back of the upper edge of the lower brick.

A **weathered joint** is one made by drawing the trowel along the joint so that the mortar at the lower edge of the joint is flush with the lower brick while the mortar at the upper edge of the joint is slightly back of the lower edge of the brick above the joint.

A **tooled joint** is made with a special tool called a *jointer*, which is described later. There are three forms of the tooled joint, which are made with jointers of different shapes. These three joints are marked as tooled with round-end, hollow round-end, and **V**-shaped jointers.

A **raked joint** is formed by scratching out the mortar to a depth of from $\frac{1}{8}$ inch to $\frac{1}{2}$ inch. This is done with special tools, which will be described later. A raked joint may have a rough finish or a smooth finish.

A **rough-cut flush joint** is formed by allowing the mortar to ooze out beyond the face of the brick and cutting off the surplus with a quick stroke of the trowel just after the mortar has begun to set, but in such a manner as to avoid smoothing the surface of the mortar.

A **rodded joint** is one that is made by cutting a line along the upper and lower edges of the joint with the edge of a trowel.

45. Examples of Finish of Joints.—A *rough-cut flush joint* is illustrated in the wall shown in Fig. 19. In this example, real Roman rough-textured brick are used with a flush joint 1 inch in width. This type of brickwork is found in ancient Roman buildings.

Fig. 20 illustrates the use of a rough-textured brick and a rough raked joint. The brick are laid up in English bond. In Fig. 29, smooth-textured mottled brick of standard size are shown laid up in Flemish bond with smooth raked joints of dark-brown mortar.

46. A mortar joint that is decidedly black or white is to be avoided. The black joint has a deadening or dulling effect on the general color of the mass of brickwork, while the white mortar looks too bright and new and generally makes too sharp a contrast in color with the brick.

47. Tools Used in Finishing Joints.—The *trowel* is used to make the struck joint and the weathered joint and, in connection with a straightedge, in forming the rodded joint.

The tooled joint is made with a tool called a *jointer*, *jointing tool*, or *jointing steel*. Forms of jointers are shown in Figs. 31, 32, and 33. The jointer shown in Fig. 31 consists of a piece



FIG. 31

of flat steel bent as shown and with the edges *d* and *e* made of different shapes so as to produce the different forms of joints. Three of these shapes are shown at *a*, *b*, and *c*. The mortar joint is finished by drawing the jointer along between the edges of the bricks and pressing it against the mortar. The jointer forms the joint according to the shape of its edge. The edge *a* makes a hollow joint, the edge *b* forms a *beaded* or projecting half-round joint, while the edge at *c* is used to form a **V**-shaped joint. These joints are shown in Fig. 30.

48. Another form of a jointing tool is one that has a circular cross-section and a tapering point, as shown in Fig. 32.



FIG. 32

The fine point at *a* is used in pointing the finer joints, and the thicker part *b* is used for coarser joints. This tool is used only for hollow joints.

A similar jointer, also circular in section, is shown in Fig. 33 (*a*). The jointer tapers so that it can be used for joints of different widths.

49. Tools for Raking Joints.—A simple device for raking the mortar out of the joints to form a raked joint is shown in Fig. 33 (b). It consists of a flat steel bar with projections on each end which are the shape of the joint to be raked. The same tool can be used for raking two different sized joints. The projection *a* or *b* is drawn along in the joint and cleans out the mortar according to its length and width. The shoulders *c* prevent the joint being scratched out beyond the desired depth.

50. A patented device for raking out and striking a raked joint is shown in Fig. 33 (c). This tool consists of a handle *a*

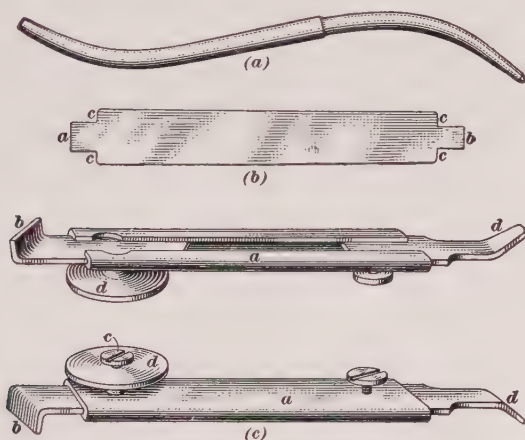


FIG. 33

into one end of which *joint scrapers*, or *plows*, *b* can be fitted. Different sizes of plows are used according to the thickness of the joints. The plow can be extended to cut any depth of joint required, and is held firmly to the handle by means of a screw bolt *c*, the head of which is shown above the wheel *d*. This wheel runs along on the face of the brick as shown in Fig. 34 at *a* and regulates the distance that the plow enters the joint. Thus, when the tool is run along the face of the wall it rakes the mortar out of the joint to the desired depth, forming a rough raked joint.

In the other end of the handle, Fig. 33 (c), *strikers d* of different widths can be secured. These strikers are used to smooth the raked joint, as shown in Fig. 34 at *b*, thus forming a smooth raked joint.

51. Pointing.—Pointing consists of scraping the mortar out of the joints to the depth of about $\frac{3}{4}$ inch and filling them with fresh mortar. The joints are raked out with a piece of

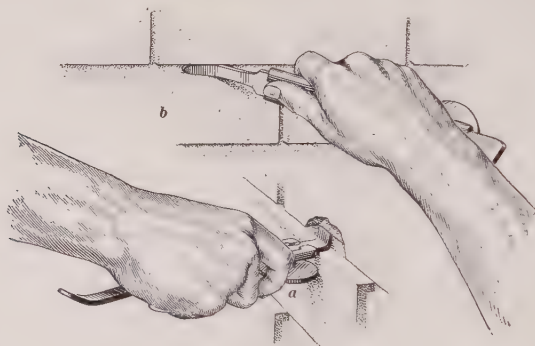


FIG. 34

wood or iron or with a tool such as has just been described. After raking, all the loose mortar should be brushed out of the joints and the joints made wet so that the pointing mortar will stick to the brickwork. The same quality of mortar should be used as for face brickwork and the joint may be finished in any of the styles shown in Fig. 30.

BOND

52. General.—The appearance of a brick surface depends not only upon the color and texture of the brick and the mortar but, to a very large extent, upon the manner in which the brick is bonded or laid in the wall.

Bonding is primarily a means of construction and is a method of tying the bricks together in such a way as to make the wall structurally solid and strong.

Face bond is the bond used on the face of the wall, and it is often independent of the structural bond of the backing.

In discussing bond or bonding in connection with face brickwork the face bond only is referred to.

53. Bonds.—There are four structural bonds that are also largely used in face brickwork. They are the *running* bond, the *Flemish* bond, the *English* bond, and the *Dutch* bond.

54. Running Bond.—The simplest bond, as far as appearance is concerned, is the *running* bond, which shows only stretchers on the face of the wall. These stretchers break joint as shown in Fig. 13. This arrangement of the bricks does not provide headers to tie the face brick to the backing, hence the tie must be provided by other means. The methods employed to tie the face brick to the backing are by means of metal ties; by clipping off the interior corners of the face brick

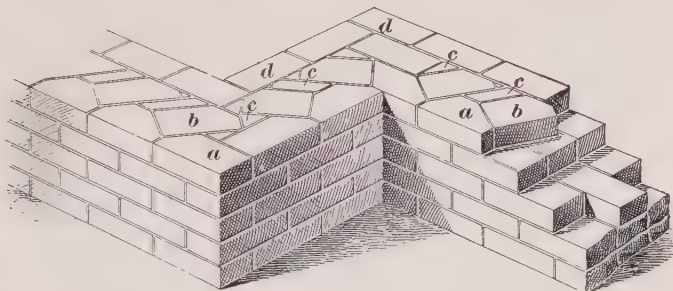


FIG. 35

and laying the interior bricks diagonally to form a bond, as shown in Fig. 35; by cutting the face brick in half lengthwise and *toothing* the backing into the space thus formed, as shown in Fig. 36.

55. Flemish Bond.—The *Flemish* bond consists of alternate headers and stretchers in each course, each header in one course being directly over the center of the stretcher in the course below. This bond is shown in Figs. 17, 18, 19, 21, 22, and 29, and is very decorative in its effect. It is particularly effective when the headers are slightly darker than the stretchers, as in Figs. 19 and 22.

A variation in this bond is illustrated in Fig. 37, where the stretcher consists of two standard-sized stretchers with a blind joint between them.

56. English Bond.—The *English* bond consists of alternate courses of headers and stretchers and is a substantial-

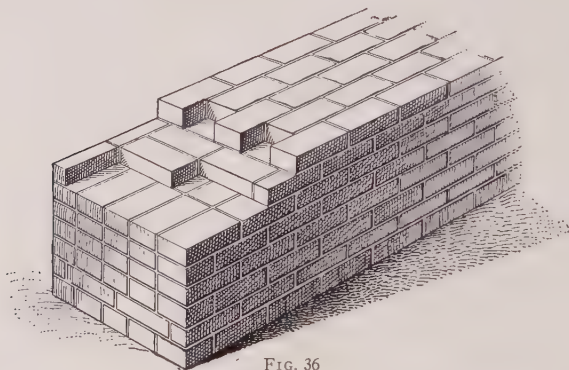


FIG. 36

looking and fine-appearing bond. It is also simple and easy to lay up.

An example of this bond is shown in Fig. 20. A great deal of the historic brickwork of England is laid in this bond and it is a very popular bond in the United States. Often, in practice,

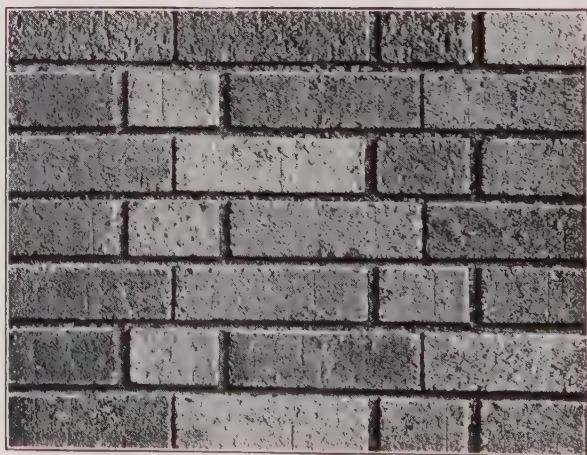


FIG. 37

only the headers of every third or fourth course in the face brick extend into the backing to form a bond or tie, or some-

times only a portion of the course extends into the backing. The stretchers in all courses are in line vertically.

57. Dutch Bond.—The *Dutch* bond is a modification of the English bond and it also consists of alternate rows of headers and stretchers. In the Dutch bond the stretchers in one course break joints with the bricks in the next stretcher course above and below, and the headers are all centered on the stretchers either above or below them. The result of this



FIG. 38

arrangement is that the vertical joints form a diagonal pattern over the entire face of the wall, which has a very artistic appearance.

This bond is also known as the *Dutch cross bond* or the *English cross bond*, and is illustrated in Fig. 38.

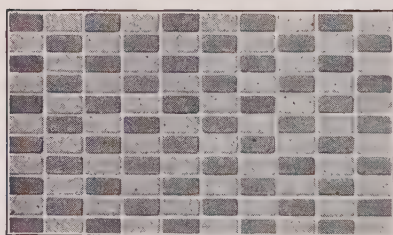
58. American, or Common, Bond.—The bond called American, or common, bond is made by introducing a course of headers, called a *bond course*, every fifth or sixth course. This bond is the one generally used in building ordinary brick walls in the United States, and is also sometimes used as a face bond.

59. Miscellaneous Bonds.—Besides the bonds that have just been described, which may be considered as the

standard bonds used in brickwork, there are many other bonds, most of which are variations of these standard bonds. These more complicated bonds, however, are used merely for their decorative effect and should properly be considered under the subject of Pattern Work.



(a)



(b)



(c)

FIG. 39

stretchers, while the patterns in (b) and (c) are formed entirely of headers. The brick in (a) must be tied to the backing as described for running bond. The brickwork in (b) and (c) can easily be tied to the backing by allowing headers to extend back into the wall as frequently as may be desired. Most of the headers shown in (b) and (c) are bats or half-bricks. These patterns may be formed by the

PATTERN WORK

60. Pattern Work on Wall Surfaces.—Pattern work is formed by arranging the bricks and joints according to some pleasing design, also by varying the color, texture, and sizes of the brick. The bonds already shown give simple and more or less pleasing patterns, and some of the more complicated bonds will next be considered.

61. Variations of the Running Bond.

Three variations of running bond are shown in Fig. 39 (a), (b), and (c). The pattern at (a) is formed of

arrangement of the joints only or by the use of bricks of different colors or textures.

62. Variations of the Flemish Bond.—The arrangement of the joints in Flemish bond does not permit of any modification but there is a great variety of pattern work that can be produced by the use of different-colored brick. Some of these patterns are shown in Fig. 40. The pattern in (c) is the one which is very popular and is used frequently.

63. Variations of the English Bond. Variations in pattern, using English bond, are made by using bricks of different colors as shown in Fig. 41.

64. Variations of the Dutch Bond.—Variations in pattern in the Dutch bond can be made only by the use of different-colored bricks. Two patterns are shown in Fig. 42.

65. Miscellaneous Patterns.—There are innumerable patterns that can be made on wall sur-

faces by manipulating the jointing and the colors of the bricks.

A great number of patterns are formed by using a course of stretchers alternating with a Flemish course. Several of these patterns are shown in Fig. 43. In (a) is shown a pattern that will have the effect of vertical lines of differing thickness;



(a)



(b)



(c)



(d)

FIG. 40

at (b) is a pattern of small crosses extending over the entire field; (c) shows a pattern in which all the headers are darker in color than the stretchers.



FIG. 41

The pattern shown at (d) has a diamond effect. The pattern at (e) is one that is formed largely by the joints and has a refined and artistic effect. A portion of wall laid up with this design, but without a difference in the brick coloring, is shown in Fig. 44.

In this particular example, rough-textured brick of various shades of reds,

browns, and soft purples, laid up with a cream-gray flush joint, gave the finished brick surface an artistic and decorative effect. Other patterns are shown in Figs. 45, 46, and 47. Intricate and exceedingly interesting patterns are shown in the Persian minaret in Fig. 8.

Various designs for wall patterns will be found in the illustrations shown in this Section and the student will find it interesting and profitable to study them and determine how they are formed.

The simplest designs to execute, so far as the mason is concerned, are those in which standard-size brick are used, and in which the pattern work does not interfere with the



FIG. 42

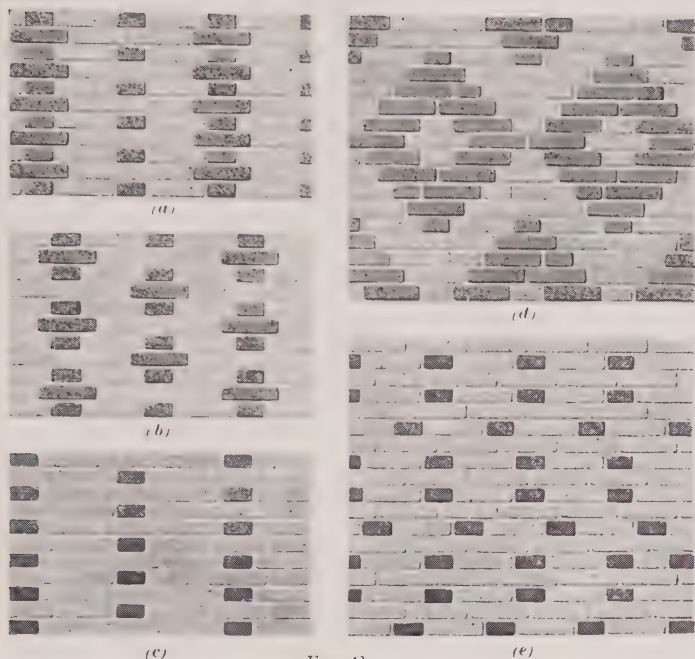


FIG. 43

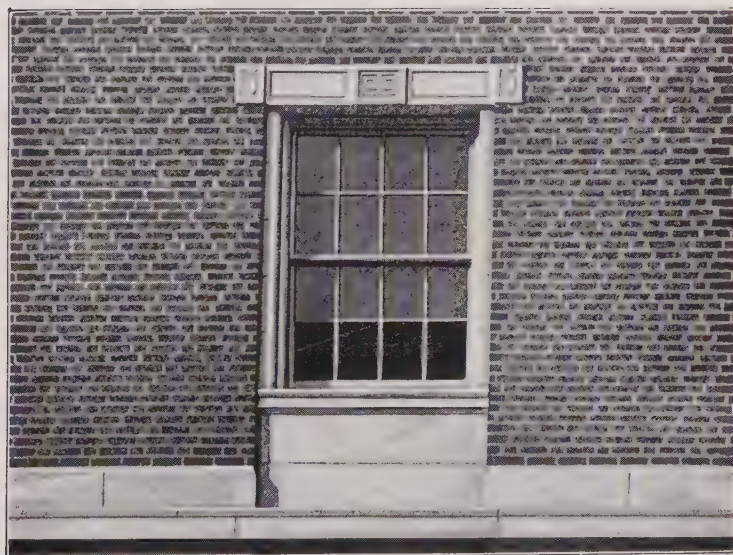


FIG. 44



FIG. 45



FIG. 46



FIG. 47

particular bond used in the general field. An example of this is shown in Fig. 48.

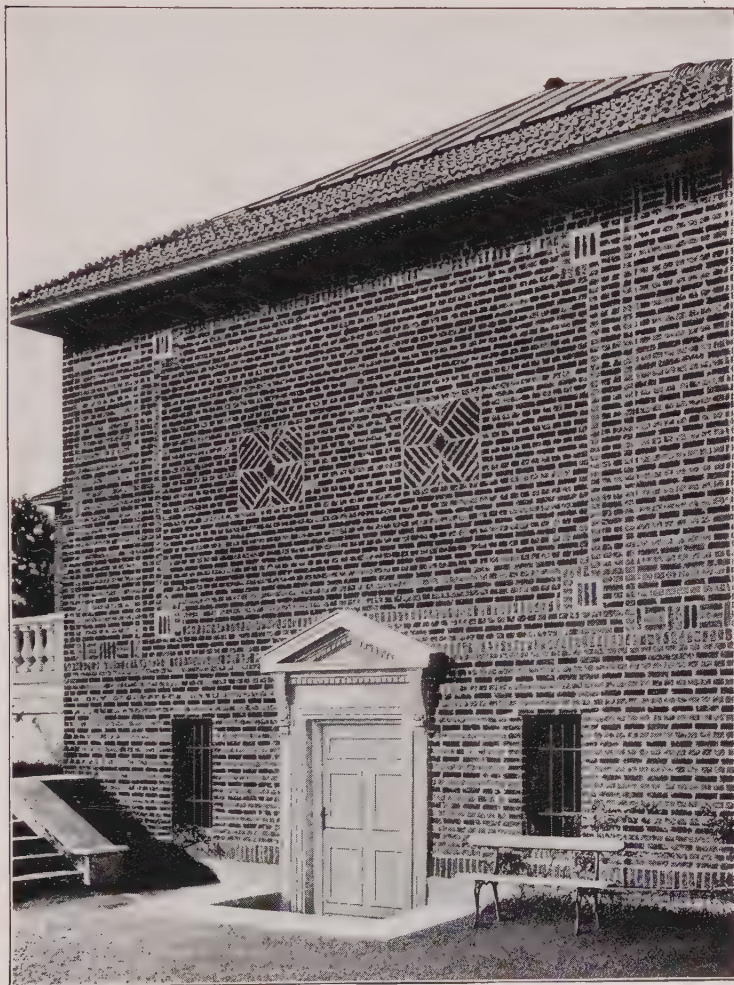


FIG. 48

66. When diagonal patterns such as shown in Figs. 43, 44, 45, and 46 are used, care should be taken in designing the façade so that the pattern will have a proper relation to the

openings and corners of the wall. Thus, the pattern should meet both sides of a window symmetrically, as shown in



By courtesy of Fiske & Co., Inc.

FIG. 49

Fig. 44, and make a neat finish at the corner of a wall, as shown in Fig. 49.

67. Herring-Bone Pattern.—A pattern known as the *herring-bone* pattern, which is very much used in paneling, is

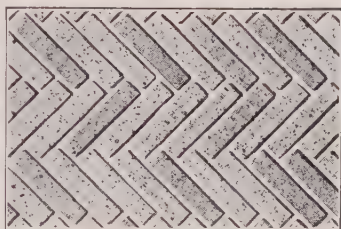
illustrated in Fig. 50. Designs such as shown in (a) are adaptable to running bands or friezes. The designs in (b) and (c) are useful for panels. These patterns, particularly (b) and (c), are also very much used in floors made of brick or tiles.

68. Friezes and Bands.—As a rule, it is best to keep the patterns used in large brick fields rather quiet and subdued and to emphasize some band or frieze or some particular spot by a more interesting and elaborate treatment. The plainness of the field will then set off to advantage the more complicated design of the frieze or spot, and produce a more satisfactory result. This method of treatment is illustrated in Figs. 51, 58, and 63, where ornamental bands are used in connection with plain fields, also in Fig. 1, where a plain field in Flemish bond is surmounted by handsome friezes or bands of patterned work which crown the wall. Fig. 51 illustrates the effectiveness of ornate bands or friezes over a plain wall.

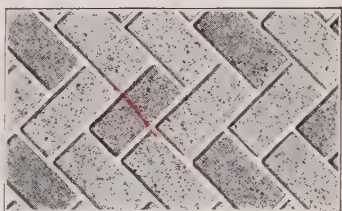
69. Designs for bands in face brickwork are given in Figs. 52, 53, and 54. Fig. 52 shows a *chain pattern* formed in Flemish bond, Fig. 53 is a *chain pattern* in English bond, and Fig. 54 is a more complicated pattern showing the use of special-sized brick, which have already been described. These effects are produced by differences in the color of the brick as well as by the bonding. Other designs for bands are shown in Figs. 1, 64, and 65.



(a)



(b)



(c)

FIG. 50



Fig. 51



FIG. 52

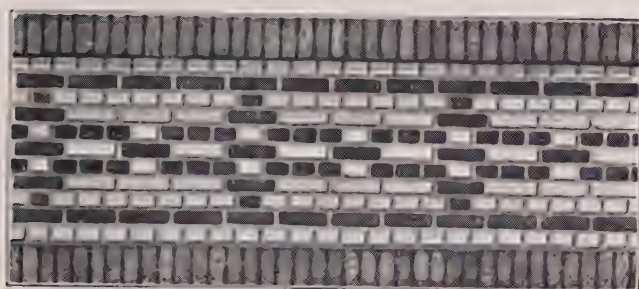


FIG. 53

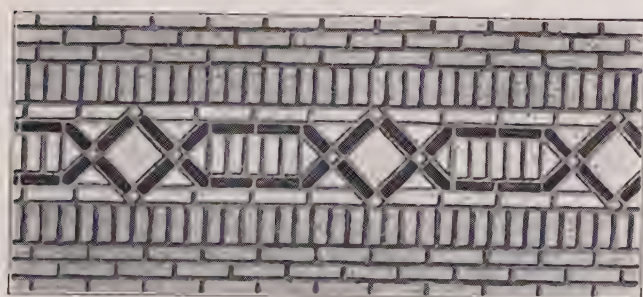


FIG. 54

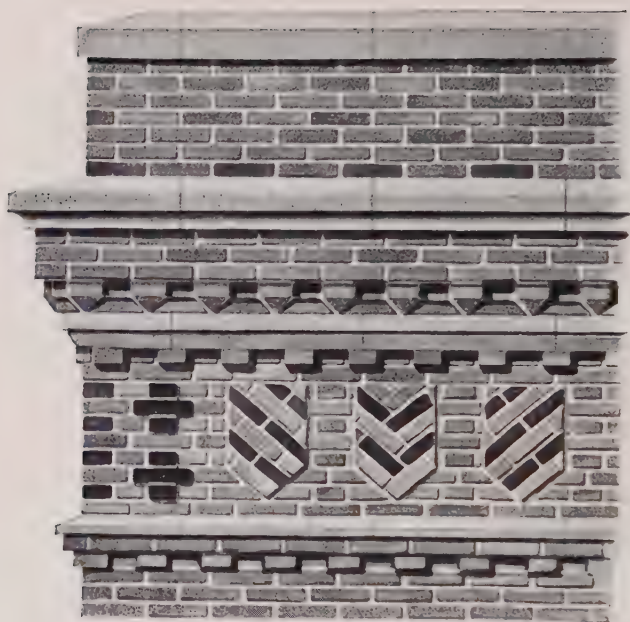


FIG. 55

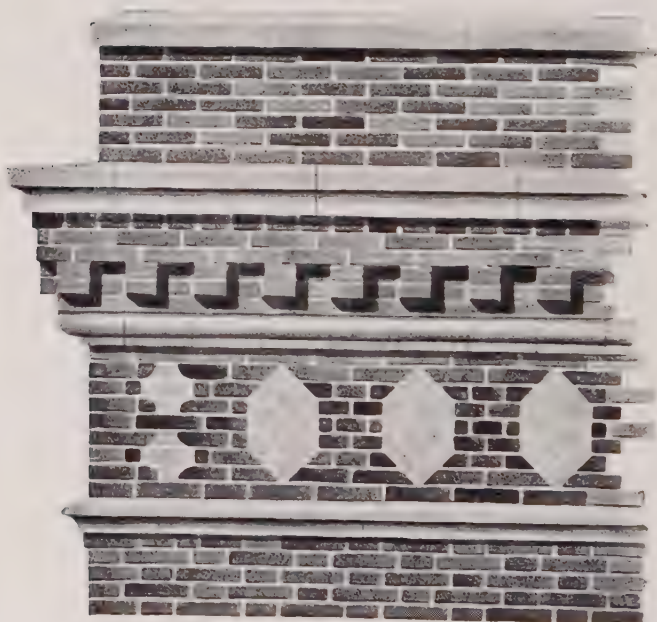


FIG. 56

Friezes containing special designs made of brick cut to various shapes and representing shields, hexagons, etc. are illustrated in Figs. 55 and 56.

70. Borders.—Borders are used around large panels such as frequently occur on school buildings, theaters, and factory buildings, which, if not especially treated, would appear uninteresting. Fig. 48 suggests a treatment of a large panel and border in a brick building which makes it interesting without using special brick and at very little expense more than would be incurred in making a plain wall.

A design for a border is shown in Fig. 57 in which the bands *a, a* as well as the corner pieces *b* are raised above the field about $\frac{1}{2}$ inch. The headers may be black headers where so indicated or else brick of a slightly darker color than the rest. The pieces *b, c*, and *d* may be tiles or bricks of special shape and different color from the brickwork of the field. A handsome border, used around a panel on an interior wall, is shown in Fig. 58.

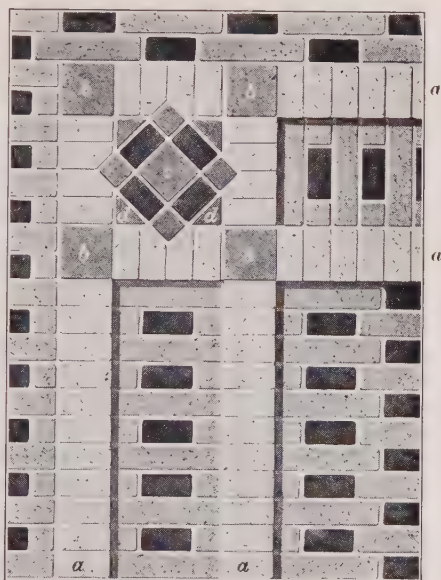


FIG. 57

71. Panels.—Panels are shown in Figs. 48, 58, 59, and 60. In Fig. 48, a large panel is formed by a border of headers and rowlocks, with the corners emphasized by bricks set on end, in soldier courses. Two points or spots in the field of this panel are brought out by special patterns. This wall is an example of a wall laid in English bond where the stretchers are darker



By courtesy of Fiske & Co., Inc.

FIG. 58

than the headers. The entire wall has a distinctly interesting brick character.

Fig. 58 illustrates a plain brick panel surrounded by an interesting border.



FIG. 59

The panel in Fig. 59 is an excellent example of modern brickwork in imitation of the ancient Persian work. There

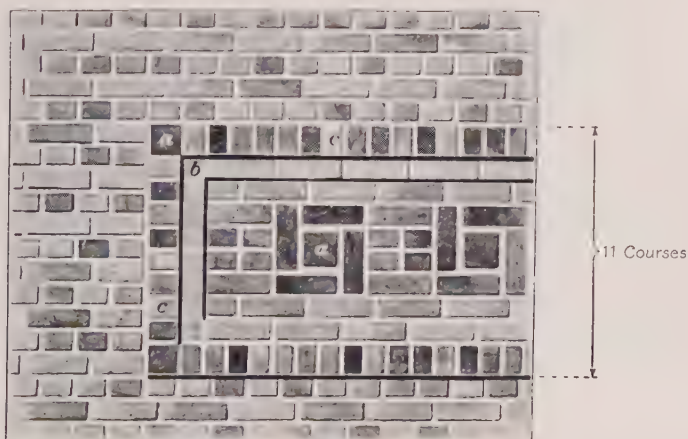


FIG. 60

are three sizes of units used in this design. The standard-size stretcher, 8 in. $\times$ 2 $\frac{1}{2}$ in., is one unit, a second is 5 in. $\times$ 2 $\frac{1}{2}$ in., and

the third is $2\frac{1}{4}$ in. $\times$ $2\frac{1}{4}$ in. The joint used in this design is $\frac{5}{8}$ inch thick, so that three rowlock bricks in the border and two joints equal one stretcher, two of the rowlocks plus one joint equal the 5-inch unit, and one rowlock equals the third

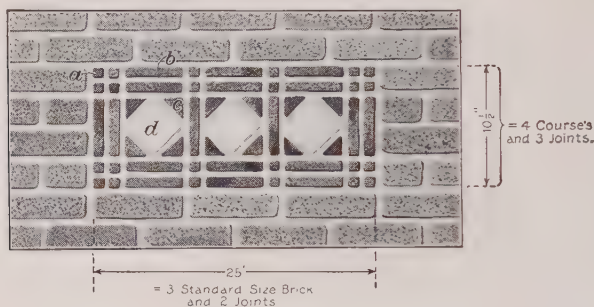


FIG. 61

unit. This combination of units lends itself to many handsome patterns. An application of this kind of panel work is shown below the frieze in Fig. 1.

Fig. 60 illustrates a simple panel design in which the border *c* has been projected slightly beyond the face of the wall. The pieces *a* and *b* are special sizes of brick made for this pattern.

The panels shown in Figs. 61 and 62 depend upon the proper selection of colors in the bricks and upon the contrast in color between the mortar and the brick. In Fig. 61 small dice 1 inch



FIG. 62

square are shown at *a*, pony size brick at *b*, triangular cuts at *c*, and square tile or brick at *d*.

The application of panels to the decoration of a building is shown in Fig. 63 immediately beneath the cornice, between the

uppermost windows, and in the frieze at the top of the bay windows.



FIG. 63

72. Interior Walls.—With the great variety of color and texture found in modern brick, interior walls can be designed that are very suitable for vestibules, conservatories,



FIG. 64

By courtesy of Fiske & Co., Inc.



By courtesy of *Flue & C. Inc.*

Fig. 65

cafés, etc. Fig. 58 illustrates the use of brick in the main entrance lobby of a large business building, in which many of

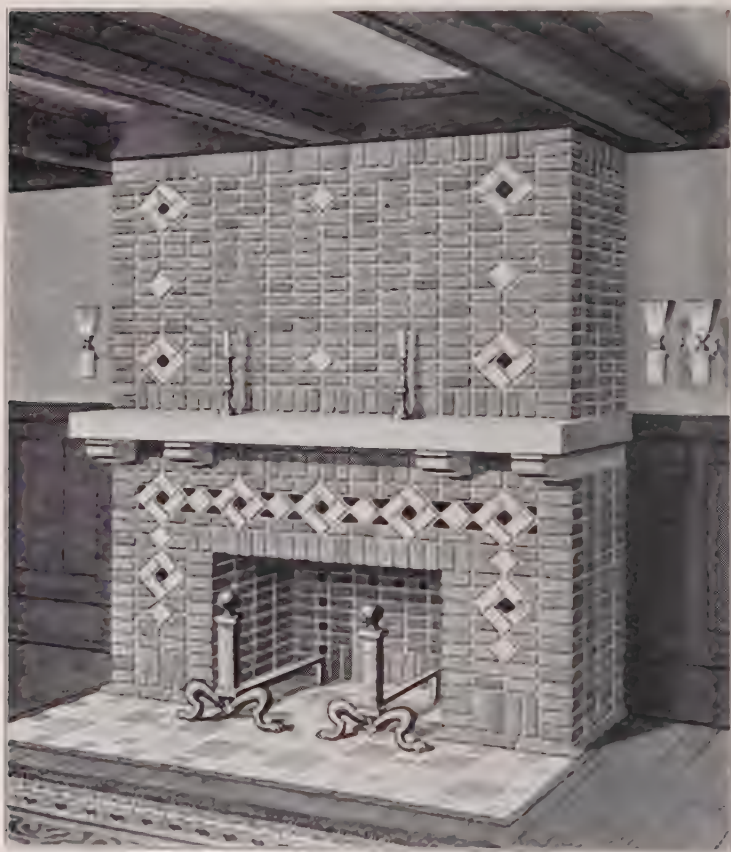
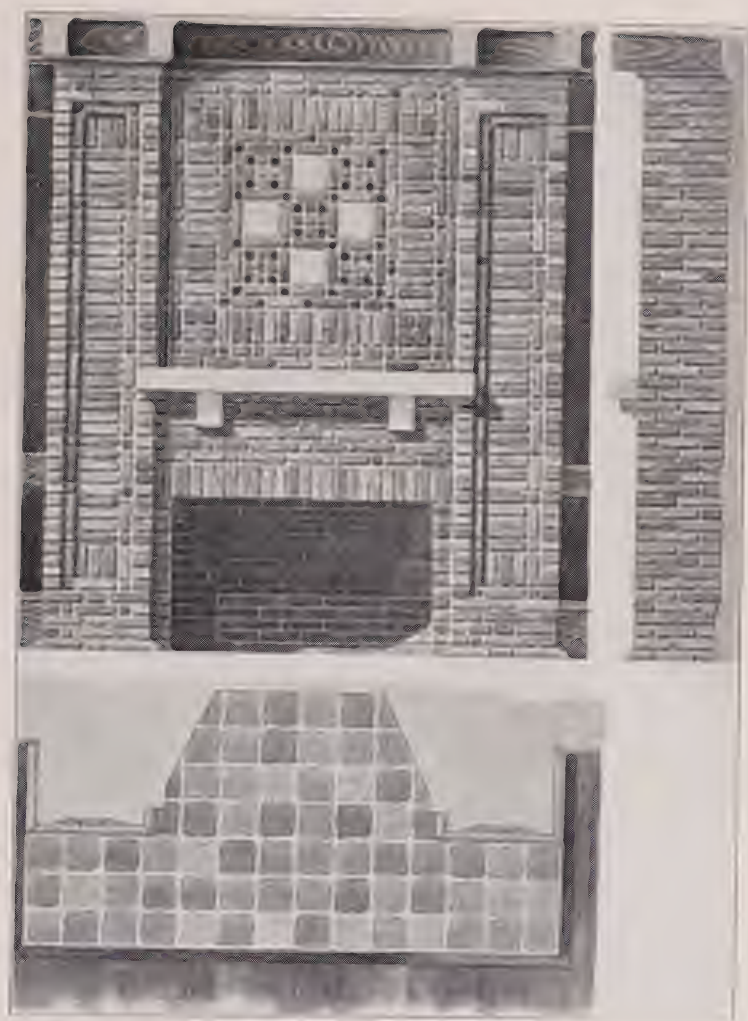


FIG. 58

the resources of face brickwork are exhibited. A soldier course occurs at the base of the wall, above which is shown a running bond of headers and a rowlock course. These form



a wainscot effect. Above this the wall is paneled, the panel being surrounded by a handsome border. The field of the panel is in Dutch bond. The trim or finish of the door openings is formed of molded brick similar in character to that of the other brick in the wall.

Figs. 64 and 65 show the treatment of walls in face brick as used in the display rooms of a prominent brick manufacturer. These walls show a variety of friezes and bonds, the use of soldier courses, friezes, bands, panels, etc. They also illustrate the use of Flemish, English, and Dutch bonds in the field, and the various special shapes of brick. Tile inserts showing dolphins and a ship are used over one doorway in Fig. 64 and an ornamented brick panel is shown over the other doorway.

73. Fireplaces.—Face brick are frequently used with artistic effect in the construction of fireplaces and chimney breasts. Figs. 66 and 67 are examples of such fireplaces. By the proper selection of colors and sizes of brick these fireplaces make very effective and ornamental features for sun parlors, living rooms, dens, and libraries.

ORNAMENTAL BRICKWORK

74. As has been stated, **ornamental brickwork** may be formed of plain brick which is built so as to project and form cornices, string-courses, and other ornamental features, or by the use of bricks which are molded into special shapes before baking.

An example of plain bricks used in forming a cornice is given in Fig. 68 in which an approximation to a classical cornice has been built as far as can be done with brick. The bottom of the cornice begins with a rowlock, or bull-header, course. Most of the projections are necessarily slight. The bold projection in the upper part of the cornice is made with especially large bricks or units which support the crowning member. A band course at the middle of this cornice is formed by building the bricks in a diagonal position so that the corners project.

This causes a variation of light and shade on the different surfaces and a wavy effect in the mortar joints. This cornice is crowned by a terra-cotta molding course. Just below the cornice are seen three tiles inserted in the brick field.



FIG. 68

Another example of ornamental brickwork formed of projecting bricks is given in Fig. 69. In this figure the outer ring of the arch is a rowlock arch and inside of this arch is a dentil

course, so called from its resemblance to a row of teeth. The string-course above the doorway is supported upon brackets



FIG. 69

formed of bricks placed on end alternating with bull headers.

Figs. 6 and 7 show examples of Italian ornamental brickwork of the 13th and 14th centuries.

CONCRETE CONSTRUCTION

MATERIALS AND METHODS

GENERAL EXPLANATIONS

1. Concrete is a mixture of cement, water, and sand, with broken stone, gravel, or cinders. When thoroughly mixed in the proper proportions and allowed to stand for a few days it becomes a hard rock-like material.

When freshly mixed it can be poured into molds or forms and will harden and take the shape of the molds. Hence, walls, columns, girders, and beams can be made by pouring concrete into properly shaped forms and allowing the concrete to harden, after which the forms may be removed.

2. Cement is a finely ground powder that will remain inactive while kept dry, but which, when mixed with water and allowed to stand for a short time, forms a hard stone-like mass.

Cement when mixed with sand and water in proper proportions forms a mortar. The cement, in hardening, binds together the particles of sand and forms a hard substance. The cement also adheres to bricks and stones between which mortar is laid, thus binding them together to make a solid wall.

3. If pieces of stone, gravel, slag, or cinders are mixed with mortar, **concrete** is formed. Its strength and usefulness depend upon the strength and proportions of the various ingredients used. In both mortar and concrete, the greater the proportion of cement that is used (within the limits of the

proportions commonly used in mortar), the stronger the resulting product will be.

4. Aggregates.—The stone, gravel, slag, and cinders entering into the composition of concrete are called *aggregates*, or *coarse aggregates*. Sand is also considered as an aggregate and is referred to as a *fine aggregate*.

5. Mixing.—The process of mixing concrete is a mechanical one and can be done by hand labor or somewhat more efficiently by machines called mixers. The process of mixing will be described later.

CEMENT

6. Description of Cement.—The cement here referred to is *Portland hydraulic cement*. It is manufactured by mixing together limestone and clay, grinding them to a powder; burning at a high temperature in a kiln; and grinding the resulting clinkers into an impalpable powder. Cement and its properties are described in the Section *Limes, Cements, and Mortars*.

7. Forms of Package.—Cement is sometimes sold in barrels, but is more generally sold in bags, as the bags are smaller than barrels and are consequently more easily handled. A bag contains about 94 lbs. and in practice is counted as 1 cu. ft. in volume. A barrel contains the equivalent of 4 bags.

8. Storing of Cement.—When cement is received on a job it should be carefully stored in a suitable shed or house until used. Such a shed should be constructed with a floor raised above the ground and formed of two thicknesses of flooring boards with a layer of waterproof paper between them. The walls and roof should also be made waterproof.

The bags of cement should be stored in the shed so that there will be a free circulation of air that will prevent dampness. The bags belonging to each shipment of cement should be piled separately so that their identity shall not be lost.

9. Testing of Cement.—It is customary for manufacturers to test the cement in each of their storage bins, and the

results of the tests of the cement from the bin from which shipment is made can be obtained by the contractor or architect if he so desires.

It is advisable, however, especially where the work in which the cement is to be used is large or important, to test the cement as it arrives at the building. This testing is best done by firms that make a practice of doing such work, who have special testing laboratories, and are generally found in all large cities.

10. When such a firm is engaged to test the cement for a building it sends a representative to the car or place where the cement is delivered and the representative secures samples of the cement in every shipment, marks the packages for identification and, if the shipments are to remain on the railroad car until examined, seals the car. The samples are taken to the laboratory, tests are made and the results compared with the standard requirements for cement as laid down by the American Society for Testing Materials. The results of the tests are formulated in reports which show the results in comparison with the standard requirements.

11. Laboratory Report.—A sample laboratory report is shown in Fig. 1. This report is made by the Pittsburgh Testing Laboratory, of Pittsburgh, Pa., on cement that was shipped for use in the construction of a General Warehouse No. 2, and was delivered at the site in railroad cars.

The report shows the results of a 7-day test and a 28-day test. The 7-day test had been previously reported but is incorporated in this report.

12. In the first vertical column are shown in larger type the required tests. At the right of the heading Laboratory Numbers is printed in smaller type Standard Specifications, Jan. 1, 1919. This indicates the date of the latest specifications prepared by the American Society for Testing Materials. Below this are the standard requirements as they relate to the different tests. The marks Pg 1578-W, Pg 1578-X, etc. at the tops of the second, third, fourth, and fifth columns are the

PITTSBURGH TESTING LABORATORY

PITTSBURGH, PA.

51st

28 Day REPORT OF TESTS OF CEMENT

P. T. L. Order No. 1707

File No. 2708,3

To Smith & Jones Concrete Construction Co.,

Pittsburgh, Pa.

Cement from Aztec Portland Cement Co.,

For General Warehouse No. 2

Order No. E 886

Sample from Car at plant by P.T.L. Inspector

Date Tested Nov. 27, '19

LABORATORY NUMBERS	Standard Specifications Jan. 1, 1918	Pg. 1578-W	Pg. 1578-X	Pg. 1578-Y	Pg. 1578-Z
TENSILE STRENGTH					
1 to 3 Ottawa Sand		230	264	252	238
		246	272	260	240
		220	282	246	238
Average 7 Days	290 lb.	232	273	253	238
TENSILE STRENGTH					
1 to 3 Ottawa Sand		366	363	370	344
		376	372	376	343
		360	351	363	339
Average 28 Days	320 lb.	367	362	370	342
TIME OF SETTING					
Initial—Gillmore Needle	Not less than 60 minutes	Hours	Minutes	Hours	Minutes
Final	Not more than 10 hours	Hours	Minutes	Hours	Minutes
		2	30	2	10
		3	00	3	00
		2	55	2	55
		5	00	4	50
		6	00	6	10
FINENESS					
Retained on No. 200 Sieve	22 per cent.	17.5	18.0	17.0	18.5
CONSTANCY OF VOLUME					
Moist Air 24 hrs. Steam 5 hrs.	Form Used	OK	OK	OK	OK
SHIPMENT					
Date		10-25-19	10-25-19	10-25-19	10-25-19
Car Initials		C.N.&W.	U. P.	A.C.L.	N.S.
Car Numbers		52478	73951	43421	20696
P. T. L. Seal Numbers		195994 A	195984 A	195942 A	195983 A
		195989 A	195960 A	195938 A	195938 A
No. of Barrels in Car		231	289	173	173
3 Copies issued to Smith & Jones Concrete Construction Co from					
		Pgh.	Office		
		No. of bbls. on order	255,000		
		No. bbls. shipped this date	866		
		Total No. bbls. shipped to date	86,004		
This Cement	MEET S the requirements of the specifications				
PITTSBURGH TESTING LABORATORY					
Frank Lak, Tester.					
E. J. Herman ENGINEER OF TESTS					

Fig. 1

laboratory marks used to identify the samples of cement taken from the different cars. Samples are taken from a number of packages in each car and a sufficient amount of cement is taken so that several tests can be made.

13. In the second, third, fourth, and fifth columns at the bottom of the report are given the dates of shipment, the initials and numbers of the railroad cars, the Pittsburgh Testing Laboratory's seal numbers, and the number of barrels of cement in each car.

The seal numbers are the numbers on the seals that are placed on the two doors of each car after the laboratory inspector has taken his samples. If these seals are broken or missing the testing company will not guarantee that the cement in the cars is the same as that they have tested.

14. Under the headings Tensile Strength, the note "1 to 3 Ottawa Sand" signifies that the samples of cement were mixed with Ottawa sand, in proportions of one part of cement to three parts of sand. The Ottawa sand is obtained in Ottawa, Ill., and is accepted as a standard so as to insure uniformity in preparing samples for testing purposes. The sand is selected so that its particles will pass through a sieve having 20 meshes to the linear inch or 400 openings to the square inch and will not pass through a sieve having 30 meshes to the linear inch or 900 openings to the square inch.

The results of the tests for tensile strength are given for samples that have hardened or set for 7 days. In the second column are shown the results of tests of three samples marked Pg 1578-W. These results are 230, 246, and 220. These are the strengths, in pounds per square inch, of the samples tested. The fourth figure, 232, is the average strength of the three samples. The requirements of the standard specifications are 200 pounds per square inch. These tests are therefore satisfactory.

The tests of the 28-day-old specimens show an average strength of 367 pounds, whereas the standard specifications call for only 300 pounds. This test is also satisfactory.

15. The standard specifications require that the cement shall gain its initial set in not less than 60 minutes and its final set in not more than 10 hours. By noting the results given for the various samples they will be seen to have passed this test satisfactorily. The Gillmore needle is a laboratory device for testing cement and will not be described here.

16. The fineness of cement is measured by sieves. The standard specification requires that not more than 22 per cent. of the cement be retained on a sieve having 200 meshes to the linear inch or 40,000 meshes to the square inch. All the samples have passed through the standard sieve leaving less than 22 per cent. on the sieve and are sufficiently fine.

17. In the constancy of volume test it is required that after a specimen has been mixed with water and exposed to moist air for 24 hours and steam for 5 hours it shall be firm and hard. The O. K. in the report indicates that the samples have met this test successfully.

The report shows that the cement in the shipment has successfully met the requirements of the Standard Specifications and this is testified to by the signatures of the tester and the engineer of tests. This is accepted by the architect as evidence that the cement is satisfactory.

AGGREGATES

18. Kinds of Aggregates.—The materials most commonly used as aggregates are sand, stone, gravel, and slag. Sand and gravel are usually obtained from natural deposits, while the rock aggregate is obtained by crushing masses of rock that are too large to be used in the concrete.

These materials must be screened or graded. By grading is meant separating the particles into various sizes. These various sizes are mixed together again, when mixing the concrete, the proper proportions of the different sizes being used so as to make the most compact mixture.

When the particles of stone are $\frac{1}{4}$ inch or less in size they are considered as sand.

19. Sand.—It is usually required that sand for concrete shall be sharp, coarse, and clean. It is not, however, so essential that the sand be sharp but it must be clean and consist of particles most of which are coarse, or about $\frac{1}{4}$ inch in diameter. Sand is clean when it is free from foreign substances such as clay, loam, and vegetable matter. Clay and loam can be removed from the sand by washing. Sand containing vegetable matter should not be used.

If there is any doubt about the suitability of a given sand it can be examined at the testing laboratories, where specimens of the proposed sand mixed with cement and standard sand mixed with cement can be tested and compared. Good building sand will give as great, and in most cases greater, strength than Ottawa sand.

20. Stone.—It is also important that the stone be clean and of the proper size and kind. If the stones are mixed with dirt or other foreign substances they can be washed. The stone, as well as the sand, should be kept clean in suitable wooden bins from which it may be taken as needed. On small jobs, however, this may be too expensive, and a wooden platform laid on the ground may be used instead.

21. Maximum Size of Stone Aggregates.—It is very important that stones of the proper size be used. The sizes of most of the stones used in concrete should be as large as possible consistent with the character of the work. These should be mixed with a proper selection of smaller stones, to fill in the voids. For large masses of concrete, stones as large as two or three inches in their greatest diameter may be used; for reinforced concrete, stones one inch in diameter are as large as can conveniently be used. For concrete blocks, very small stones are sometimes used, but sometimes they are omitted, as the blocks are generally made hollow and with thin shells and webs that are not thick enough to accommodate large pieces of aggregate.

When the dimensions of the concrete work are very large, stones of considerable size are often bedded in the concrete with the object of saving cement, sand, and labor in mixing

concrete. In architectural work, however, concrete work of large dimensions is not often employed, and such stones are rarely used.

22. Value of Different Kinds of Stone.—The relative value of different kinds of stone for aggregates is about as follows: Trap, granite, gravel, sandstone, hard limestone, and soft limestone. Other materials that may be used as aggregates are slag, shale, slate, and cinders.

23. The most effective stone to use as an aggregate is *trap rock*, which is a rock of igneous origin. This stone is very tough and strong. *Granites* are also strong and suitable, as they are very hard and durable. *Limestones* of the harder kinds are also satisfactory, as are also the harder kinds of *sandstones*. *Slate* and *shale*, unless of very solid and durable character, should be used only when no better material can be obtained, as they are subject to disintegration.

24. *Slag* of certain kinds makes an excellent aggregate and has the advantage of being lighter than stone and consequently making a concrete that is light in weight and at the same time as strong as some of the stone concretes.

25. *Cinders* are comparatively light in weight and are useful in making concrete for fireproofing purposes. Cinder concrete will add less to the weight of a structure than stone concrete.

PROPORTIONING OF INGREDIENTS

PROPER PROPORTIONS

26. Proportioning of Mortar.—Since in forming mortar the cement acts as a binder between the grains of sand, there must be enough cement in the mortar to coat completely each grain of sand with cement and to fill the spaces, called *voids*, between the grains. The amount of cement actually used must, therefore, be sufficient both to coat the grains and to fill the voids. It follows that the smaller the voids, the less cement

will be needed; and since the cement is the expensive ingredient of the concrete, it is most economical to use sand having few voids. Such a sand is one consisting of particles of many sizes, from coarse to fine, but with the coarse particles predominating.

27. With sand having the properties just described, a very strong and dense mortar can be obtained by mixing one part of cement to two parts of sand. This mixture is called a 1 : 2 mortar and is a mixture very frequently used. Where greater strength is required, the amount of sand used may be reduced, and a 1 : 1 or 1 : 1½ mixture used. Where the strength is not very important, the sand ingredient may be increased to three parts for each part of cement, making the mortar a 1 : 3 mixture. Mortar concrete containing a large proportion of cement is called *rich*; that with a small proportion of cement is called *lean*.

28. Measuring by Volume.—The various ingredients that enter into the making of mortar and concrete are measured by volume. In practice, when it is desired to make mortar, the cement is measured by taking one or more bags of cement, each of which counts as 1 cubic foot, and one or more cubic feet of sand. If the cement has been shipped in barrels, the ratio is determined in a similar manner, the barrel containing an equivalent of four bags of cement, or 4 cubic feet. The sand is usually measured in wheelbarrows, the cubical contents of the wheelbarrow having been previously determined by a test. If a 1 : 2 mixture is desired, a wheelbarrow which will hold 2 cubic feet is filled with sand and this sand and one bag of cement would be mixed together. The amount mixed at any one time is called a **batch**. A batch is called a one-bag batch if only one bag of cement is used, or a two-bag batch if two bags are used, and so forth. How the mixing is actually done will be described presently in connection with concrete.

29. Proportioning Concrete.—The mortar which serves as a binder between the coarse aggregates in the concrete, must be sufficient in quantity not only to coat each stone, but

TABLE I
QUANTITIES OF INGREDIENTS FOR CONCRETE OF VARIOUS PROPORTIONS

Proportion of Ingredients			Ingredients Required for 1 Cubic Yard of Rammed Concrete											
			Stone, 1 Inch and Under— Dust Screened Out			Stone, 1½ Inches and Under—Dust Screened Out			Stone, 2½ Inches—With Most Small Stone Screened Out			Gravel, ¾ Inch and Under		
Cement	Sand	Stone	Cement Barrels	Sand Cubic Yard	Stone Cubic Yard	Cement Barrels	Sand Cubic Yard	Stone Cubic Yards	Cement Barrels	Sand Cubic Yard	Stone Cubic Yards	Cement Barrels	Sand Cubic Yard	Gravel Cubic Yard
1	1.0	2.0	2.57	.39	.78	2.63	.40	.80	2.72	.41	.83	2.30	.35	.74
1	1.0	2.5	2.29	.35	.88	2.34	.36	.89	2.41	.37	.92	2.10	.32	.80
1	1.0	3.0	2.06	.31	.94	2.10	.32	.96	2.16	.33	.98	1.89	.29	.86
1	1.0	3.5	1.84	.28	.98	1.88	.29	1.00	1.88	.29	1.05	1.71	.26	.91
1	1.5	2.5	2.05	.47	.78	2.09	.48	.80	2.16	.49	.82	1.83	.42	.73
1	1.5	3.0	1.85	.42	.84	1.90	.43	.87	1.96	.45	.89	1.71	.39	.78
1	1.5	3.5	1.72	.39	.91	1.74	.40	.93	1.79	.41	.96	1.57	.36	.83
1	1.5	4.0	1.57	.36	.96	1.61	.37	.98	1.64	.38	1.00	1.46	.33	.88
1	1.5	4.5	1.43	.33	.98	1.46	.33	1.00	1.51	.35	1.06	1.34	.31	.91
1	2.0	3.0	1.70	.52	.77	1.73	.53	.79	1.78	.54	.81	1.54	.47	.73
1	2.0	3.5	1.57	.48	.83	1.61	.49	.85	1.66	.50	.88	1.44	.44	.77
1	2.0	4.0	1.46	.44	.89	1.48	.45	.90	1.53	.47	.93	1.34	.41	.81
1	2.0	4.5	1.36	.42	.93	1.38	.42	.95	1.43	.43	.98	1.26	.38	.86
1	2.0	5.0	1.27	.39	.97	1.29	.39	.98	1.33	.39	1.03	1.17	.36	.89
1	2.5	3.5	1.45	.55	.77	1.48	.56	.79	1.51	.58	.81	1.32	.50	.70

I	2.5	4.0	1.35	.52	.82	1.38	.53	.84	1.42	.54	.87	1.24	.47	.75
I	2.5	4.5	1.27	.48	.87	1.29	.49	.88	1.33	.51	.91	1.16	.44	.80
I	2.5	5.0	1.19	.46	.91	1.21	.46	.92	1.26	.48	.96	1.10	.42	.82
I	2.5	5.5	1.13	.43	.94	1.15	.44	.96	1.18	.44	.99	1.03	.39	.86
I	2.5	6.0	1.07	.41	.97	1.07	.41	.98	1.10	.41	1.03	.98	.37	.89
I	3.0	4.0	1.26	.58	.77	1.28	.58	.78	1.32	.60	.80	1.15	.52	.72
I	3.0	4.5	1.18	.54	.81	1.20	.55	.82	1.24	.57	.85	1.09	.50	.75
I	3.0	5.0	1.11	.51	.85	1.14	.52	.87	1.17	.54	.89	1.03	.47	.78
I	3.0	5.5	1.06	.48	.89	1.07	.49	.90	1.11	.51	.93	.97	.44	.81
I	3.0	6.0	1.01	.46	.92	1.02	.47	.93	1.06	.48	.97	.92	.42	.84
I	3.0	6.5	.96	.44	.95	.98	.44	.96	1.00	.45	1.01	.88	.40	.87
I	3.0	7.0	.91	.42	.97	.92	.42	.98	.94	.42	1.05	.84	.38	.89
I	3.5	5.0	1.05	.56	.80	1.07	.57	.82	1.11	.59	.85	.96	.50	.76
I	3.5	5.5	1.00	.53	.84	1.02	.54	.85	1.06	.56	.89	.92	.48	.78
I	3.5	6.0	.95	.50	.87	.97	.51	.89	1.00	.53	.92	.88	.46	.80
I	3.5	6.5	.92	.49	.91	.93	.49	.92	.96	.51	.95	.83	.44	.82
I	3.5	7.0	.87	.47	.93	.89	.47	.95	.91	.49	.98	.80	.43	.85
I	3.5	7.5	.84	.45	.96	.86	.45	.98	.86	.47	1.01	.76	.41	.87
I	3.5	8.0	.80	.42	.97	.82	.43	.1.01	.81	.45	1.04	.73	.39	.89
I	4.0	6.0	.90	.55	.82	.92	.56	.84	.95	.58	.87	.83	.51	.77
I	4.0	6.5	.87	.53	.85	.88	.53	.87	.91	.55	.90	.80	.49	.79
I	4.0	7.0	.83	.51	.89	.84	.51	.90	.87	.53	.93	.77	.47	.81
I	4.0	7.5	.80	.49	.91	.81	.50	.93	.84	.51	.96	.73	.44	.83
I	4.0	8.0	.77	.47	.93	.78	.48	.95	.81	.49	.98	.71	.43	.86
I	4.0	8.5	.74	.45	.95	.76	.46	.98	.78	.47	1.01	.68	.42	.88
I	4.0	9.0	.71	.43	.97	.73	.44	1.01	.75	.45	1.04	.65	.40	.89
I	5.0	9.0	.66	.50	.90	.67	.52	.93	.70	.53	.96	.61	.46	.83
I	5.0	10.0	.62	.47	.95	.63	.48	.96	.65	.50	1.00	.57	.43	.87

also to fill the voids between the stones. The voids between the stones are smallest when the stones are not all of the same size but vary from the coarsest down to the $\frac{1}{4}$ -inch size. For such stones a commonly used mixture is one part of cement, two parts of sand, and four parts of stone, commonly written 1 : 2 : 4; but richer mixtures, such as 1 : $1\frac{1}{2}$: 3, are occasionally used for very thin reinforced-concrete sections and columns, also for certain kinds of concrete pavements. Leaner mixtures, such as 1 : $2\frac{1}{2}$: 5, are frequently used in architectural work for basement walls and the like. The mixture 1 : 3 : 6 is about as lean as concrete should be mixed. This mixture may be used for heavy walls, also for cellar floors where it is intended to cover the concrete with a wearing surface of some kind, such as a wooden floor or a cement finishing coat. It is also used in making cinder concrete that is used to fill in over slabs of concrete which are used in fireproof floors.

30. Quantities of Materials Required for Concrete.

Concrete is usually measured by the cubic yard, and tables giving the quantities of materials are usually based upon the cubic yard as a unit. There are 27 cubic feet in a cubic yard.

The amounts of cement, sand, and stone required to make up 1 cubic yard of concrete vary with the mixture, a richer concrete requiring more cement per cubic yard than a lean concrete. The quantities also vary according to whether the aggregates are well graded in size or not.

31. Table I.—Table I gives the quantities of ingredients that will be required to make 1 cubic yard of rammed concrete, or concrete that is tamped or rammed into its position, when the ingredients are used in different proportions. It is assumed that materials of average quality are used such as will customarily be employed in actual practice. The following example will illustrate the use of this table:

EXAMPLE.—What quantities of the various ingredients will be required to make 20 cubic yards of 1 : 2 : 4 stone concrete, using stone 1 inch and under in diameter with the dust screened out?

SOLUTION.—In Table I it will be seen that for a 1 : 2 : 4 mixture, using 1-inch stone and under with dust screened out, 1.46 bbl. of cement,

.44 cu. yd. of sand, and .89 cu. yd. of stone will be required to make 1 cu. yd. of concrete. For 20 cu. yd. of concrete the following will be required:

$$\left. \begin{array}{l} 20 \times 1.46 = 29.20 \text{ bbl., or 117 bags of cement} \\ 20 \times .44 = 8.80 \text{ cu. yd. or 9 cu. yd. of sand} \\ 20 \times .89 = 17.80 \text{ cu. yd. or 18 cu. yd. of stone} \end{array} \right\} \text{Ans.}$$

When estimating the quantities required for a given job, an allowance of about 5 per cent. additional should be made for waste.

32. Amount of Water Required.—The amount of water required in concrete varies greatly, because the concrete may be mixed wetter or drier, and also because the materials may absorb a smaller or a greater quantity of water. The proportion of cement used also has a great influence upon the amount of water used. However, as a rough approximation, it may be stated that it takes one gallon of water to each cubic foot of the solid ingredients used in the batch.

33. Consistency of Concrete.—Concrete mixtures are usually classed as *dry*, *medium*, or *wet*, according to the amount of water used in them. The concrete generally used for construction work is a medium mixture, which produces a concrete of such consistency that it will flow sluggishly into the forms without separation of the materials. If less water is used, the mixture becomes so stiff that it cannot be properly placed in the forms. If more water be used, the aggregates settle in the mass and cause pockets of water to be formed which produce voids in the finished concrete or a soft chalk-like product is formed that has no strength.

If too much or too little water is used, there is a loss of density and strength as compared with concrete of the proper consistency.

MIXING OF CONCRETE

34. Methods of Mixing Concrete.—There are two methods of mixing concrete, namely, by hand and by machine. Concrete is mixed by hand where only small quantities are required and where a machine is not available. Machine-mixed concrete is greatly to be preferred because the ingredients are

more uniformly mixed, and the concrete is turned out more rapidly and usually at less cost for labor.

The quantity of concrete mixed in one operation is called a *batch*. The mixing operation comprises the measuring of the several materials required for the batch, the conveying of the materials to the place where they are to be mixed, the mixing and the delivery of the concrete to the tower, elevator, conveyors, or other means by which the concrete is taken to its destination.

HAND MIXING

35. The arrangement of the apparatus required for mixing concrete by hand is shown in Fig. 2. In (*a*) are shown the mixing board at *a*, the water supply at *b*, a quantity of cement in bags at *c*, a pile of sand at *d*, and a pile of broken stone or other coarse aggregate at *e*. Boards *f* form a runway for the wheelbarrows by means of which the sand and coarse aggregate are conveyed to the platform.

36. Assume that a two-bag batch of stone concrete is to be mixed in the proportions 1 : 2 : 4. There will be needed 2 bags of cement, 4 cubic feet of sand, and 8 cubic feet of stone for each batch.

The 2 bags of cement are counted as 2 cubic feet. To measure 4 cubic feet of sand, a box is made which is 2 feet square, 1 foot deep, and without a bottom. This box is placed on the mixing board and sand is brought in wheelbarrows and dumped into it until the box is exactly filled. The sand in the box is leveled off and the box is raised by means of the projecting sides, which are formed into handles. The sand is then spread out in an even layer, and on top of this the cement is evenly spread as indicated in (*b*).

37. Laborers stationed at the points *x* and *y* begin to mix the cement and sand by each taking a shovelful and turning it over at the spaces marked 1 and 2. The material is shaken off the shovels instead of being merely dumped off. Each man works on his own side of the dividing line *A A*, until all the cement and sand has been turned over. The operation is then

reversed and all the material is shoveled back to the first position. The mixed cement and sand are then in a layer on one side of the board, as indicated in (c).

38. A stone-measuring box *a*, 2 feet wide by 4 feet long and 1 foot deep, which will hold exactly 8 cubic feet, is placed

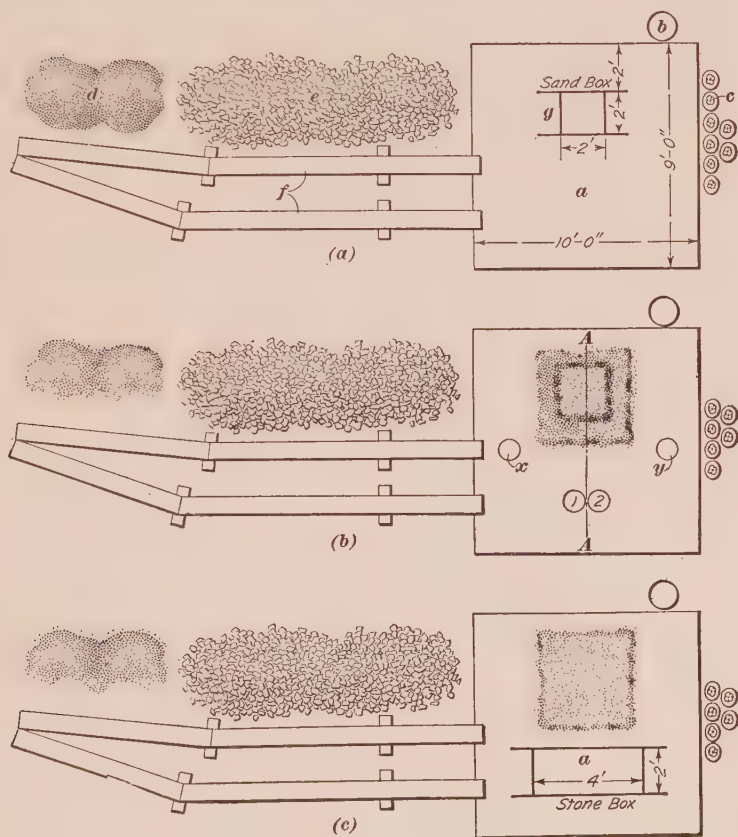


FIG. 2

alongside the sand-and-cement mixture and filled from the supply pile of stones. This box, which is also without bottom, is lifted up and removed, and the stone is shoveled over the sand-and-cement pile. The mass is then turned over as before, water being added gradually from a bucket. This turning

operation is repeated three times, after which there should be no streaks of different color in the pile, but the entire mass of concrete should be of uniform color and consistency. The concrete is then shoveled into wheelbarrows and wheeled to its destination.

39. As has been stated under the heading of Proportioning of Mortar, the measuring of the aggregates is usually done in wheelbarrows instead of boxes, although the method of using boxes is more accurate. The use of the wheelbarrow is economical in time and more convenient, but it is advisable to specify that the materials shall be mixed by the use of boxes, though the contractor may be allowed to use the wheelbarrow method as long as it is carefully done.

The contents of the wheelbarrow should be accurately ascertained so that the amount of aggregates shall be in proper proportion to the cement.

MACHINE MIXING

40. Mixing Machines.—There are two types of mechanical concrete mixers, known as *batch mixers* and *continuous mixers*. The batch mixers are designed to receive a given quantity or batch of materials, which is placed in the machine, thoroughly mixed, and discharged into buckets or wheelbarrows. The machine is then supplied with a new batch of materials and the process repeated. In the continuous mixers, as the name implies, the materials are supplied, mixed, and the concrete is discharged continuously, unless the machine is stopped. In these mixers there is always a possibility that the spouts, bins, or hoppers, from which the various materials are fed to the machine, may become clogged or stopped up, thus causing the ingredients to be fed in different proportions than were intended. This may lead to serious imperfections in the quality of the concrete.

41. Batch Mixers.—There are several kinds of batch mixers, one of the most common forms of which is illustrated in Fig. 3. At *a* is shown a receptacle, called an *automatic skip*, *side loader*, or *pivot hopper*, into which the amounts of cement,

sand, and stone necessary to make one batch are dumped. The skip is then elevated by means of ropes and pulleys to the position shown by the dotted lines *b*, when the materials will slide out into the drum *c*. A measured amount of water is introduced from the tank *e*. The drum revolves and lifts the cement, sand, and stone up inside the drum by means of blades that are riveted to the inside. When the material reaches the

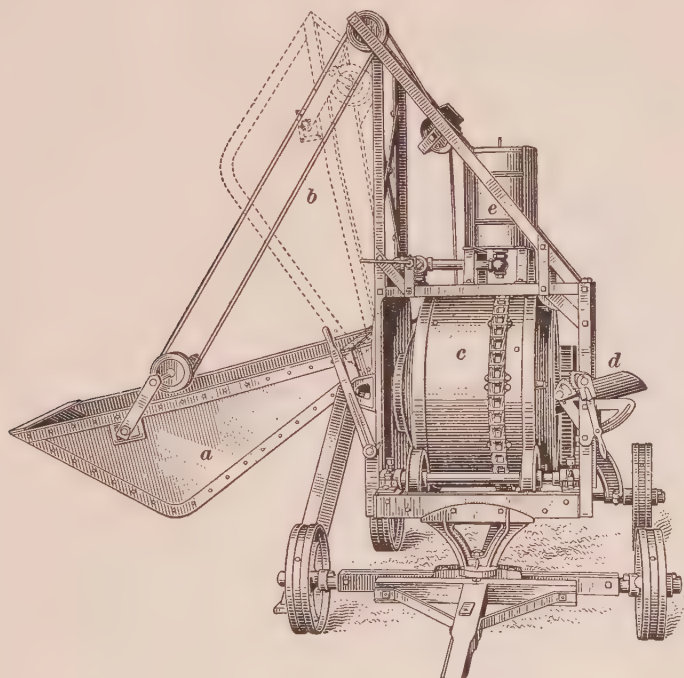


FIG. 3

top of the drum it is dropped to the bottom and picked up by other blades. This process is rapidly repeated and the materials become thoroughly mixed.

To discharge the mixed concrete, a small chute *d* is swung into the opening on the side of the drum opposite to that from which the materials enter and the concrete falling upon the upper end of this chute slides out into wheelbarrows, conveyors, or buckets.

42. While the mixing is going on in the drum, the skip is lowered and measured quantities of materials to form another batch are placed in it. When the mixed concrete has been discharged, the skip is raised and the new batch is dumped into the drum and is mixed and discharged. It will thus be seen that this process is practically a continuous one, but that concrete of the proper proportions can always be obtained.

43. Batch mixers may be driven by steam, gasoline, or electric power. For very large work, mixers operating by the action of compressed air have been used, but the installation of such huge machines is too expensive for the class of work with

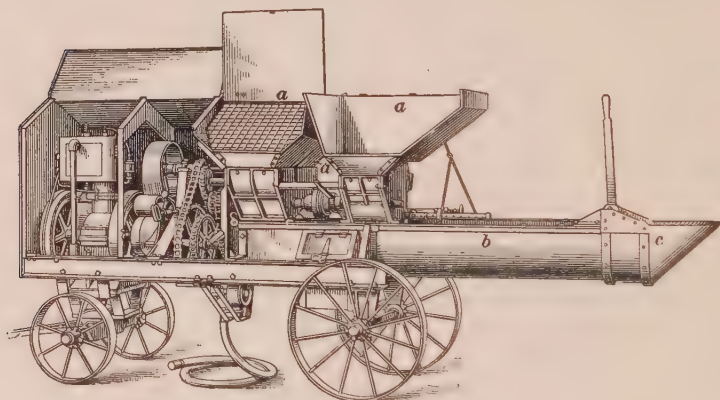


FIG. 4

which the architect is identified, being used mostly for purely engineering works such as tunnels and foundations requiring large quantities of concrete.

44. Continuous Mixers.—Continuous mixers usually consist of a feeding device and a trough in which is a screw that mixes and pushes the concrete from one end of the trough to the other. One form of such mixer is shown in Fig. 4. At *a* are hoppers that constitute the feeding device. These hoppers contain the cement, sand, and stone and are provided with slides which are used to gauge the amount of materials that are fed into the mixing trough.

The screw in the mixing trough *b* is not a solid screw which would merely push the materials forward, but is divided with blades which also mix the concrete while pushing it to the point *c*, where it is discharged. In this form of mixer the materials are shoveled into the hoppers, and special care must be taken that the hoppers do not become empty while the machine is in operation or the mixture will be deficient in some of the necessary ingredients.

45. Water Supply.—One important feature of all concrete mixers is the device for supplying water. In continuous mixers the water is usually fed to the concrete through a pipe over the mixing trough and extending parallel with it. This pipe is perforated with holes which allow the water to escape gradually so as to feed the water to the mixture along a portion of the length of the mixing trough.

In batch mixers, a tank *c*, Fig. 3, is usually mounted over the drum. This tank has an outlet into the mixer drum and every time the mixer is loaded a constant quantity of water is drawn from the tank into the mixer. The tank can be adjusted to give any desired quantity and so long as the setting of the adjustment is left undisturbed the tank will deliver the same constant amount of water to each batch, thus making for uniformity in the consistency of the concrete.

46. Mixing in Cold Weather.—If concrete is mixed in very cold weather, every precaution should be taken not to incorporate frozen materials in the mixture. This may be guarded against by heating the sand, stone, and water before they are placed in the mixer. The sand and stone are often heated by means of steam pipes which run through the piles, although any other method may be used which will be equally effective.

Concrete which is mixed and deposited during cold weather requires also to be protected against freezing. The manner in which this is accomplished will be described later.

CONVEYING OF CONCRETE

47. Methods Used.—Concrete may be delivered at the forms by any of several methods. It may be discharged from the mixer into wheelbarrows or carts and wheeled directly to the forms. It may be discharged from the mixing machine into wheelbarrows or carts which are raised by means of an elevator to the height required by the construction and wheeled from the elevator to the forms. It may be discharged from the mixer into buckets which are raised by an elevator to a desired height where the buckets are tilted automatically and the concrete discharged into a bin. From this bin it may be discharged into wheelbarrows or carts and wheeled to the forms or it may be discharged from the bin into spouts or chutes that are inclined sufficiently to cause the concrete to flow under its own weight down the chutes to the forms that are to be filled.

48. The method of wheeling directly to the forms is most commonly used on small structures or for those which are located below the level of the mixing equipment, as the wheeling of concrete can be undertaken only on a down grade or on the level. Elevating the loaded wheelbarrows or carts is employed when temporary lifts for hoisting materials have been installed in the building and can be used in hoisting wheelbarrows of concrete rapidly from the ground floor to the level at which it is to be poured.

49. When large quantities of concrete are required or the structure is of a large area, however, the elevator and a spouting system will be found to be a cheaper method of handling the concrete, since there is very little labor required and this saving in the cost of labor will offset the cost of the special equipment.

In the great majority of cases it becomes necessary to elevate the concrete before it is conveyed, and a concreting plant thus includes an elevating and distributing system as will be described later.

50. Wheelbarrows, Carts, and Cars.—Concrete is frequently wheeled by means of the familiar wheelbarrow propelled by a laborer.

This method is, however, not economical, because only 2 or 3 cubic feet of concrete can be wheeled in a wheelbarrow without spilling. The concrete cart, Fig. 5, holds from 5 to 6 cubic feet, and since the load is balanced over the large wheels, the laborers

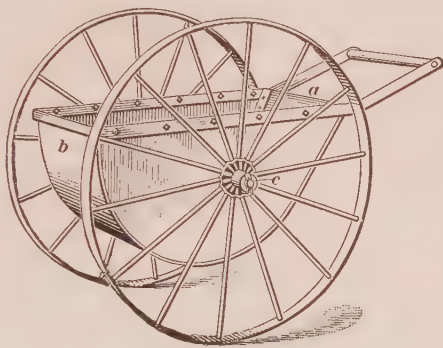


FIG. 5

have to exert themselves no more to convey the large amount in the cart than the small quantity in the wheelbarrow, if the runways are level; if the concrete has to be raised ever so little, the cart is too heavy for one man. If it is desired to wheel still larger quantities, the hopper car shown in Fig. 6 is used. This car is made in many sizes to hold from 15 to 54 cubic feet of concrete. It is always propelled by machinery, and runs on tracks. On the bottom is a gate *a*, with a handle *b* for its operation. The concrete issues from this gate in a wide

stream but this stream is easily regulated, thus making it possible to fill thin walls directly from the car.

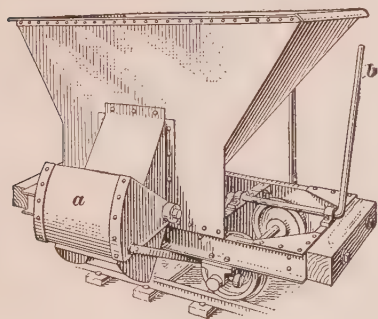


FIG. 6

51. Concrete Elevators of Wood.—A concrete elevator or tower, in which the concrete is raised in a bucket, is illustrated in Figs. 7 and 8. Such a tower is generally constructed of wood and consists

of corner posts which are securely framed together and braced as shown at *a*. At *b* is a bucket which is hoisted up and down

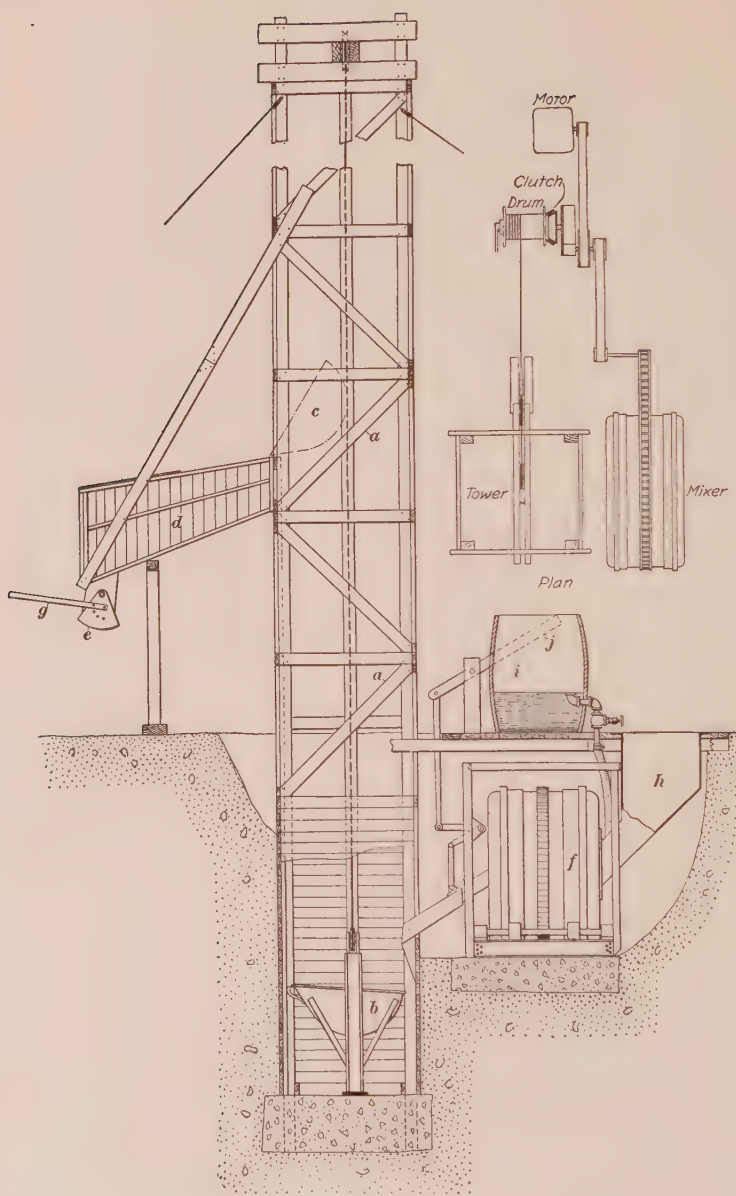


FIG. 7

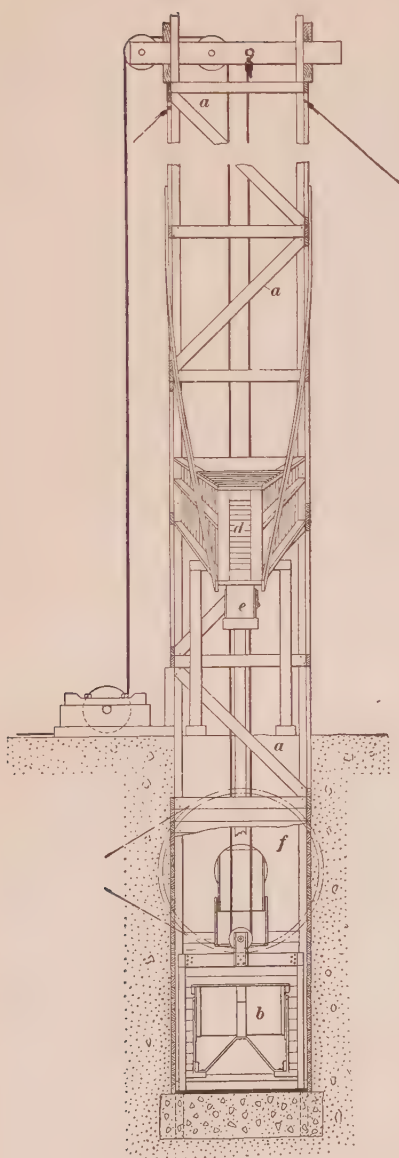


FIG. 8

in the tower and conveys the concrete to the desired level. As shown at *b* it is in the position where it is filled with concrete from the batch mixer *f*; it is also shown dotted at *c* in its position when discharging the concrete into the hopper *d*. From the hopper the concrete is discharged into carts through the gate *e*, which is opened and closed by the lever handle *g*. To prevent delay, the hopper *d* is designed to hold a supply of concrete so that the carts can be loaded while the bucket *b* is being refilled.

The ingredients for making the concrete are dumped into the chute *h*, which deposits them directly into the mixer *f*. The water is supplied from the barrel *i*. When the batch has been mixed, the handle *j* is raised as shown and the mixed concrete is deposited in the bucket *b*, which is then hoisted.

The mixer sets on a concrete platform, which is left in place when the building is finished. The posts of the tower are likewise supported in a bed of concrete. When the tower

is removed the posts are cut off just above the concrete and the concrete base is left in the ground and covered up.

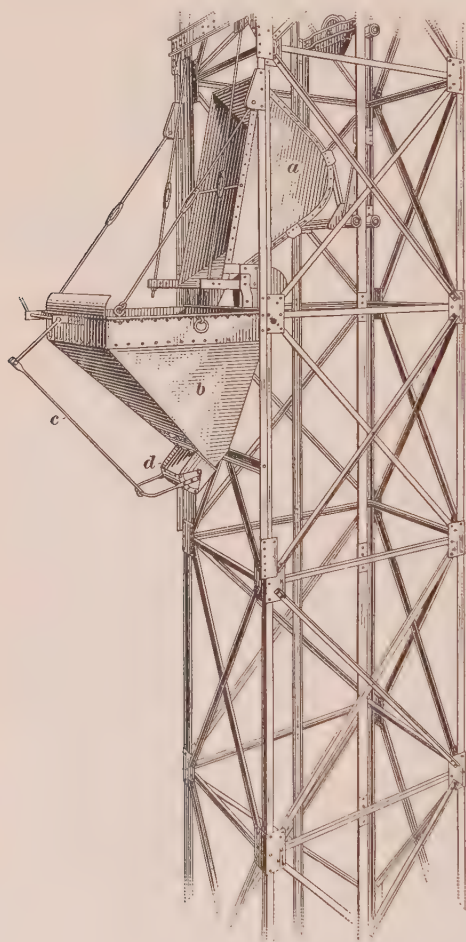


FIG. 9

expense, if properly taken down and cleaned after each structure has been completed.

53. In Fig. 9 is shown a portion of a steel-frame tower. At *a* is shown the bucket in a tilted position as it appears when the concrete is being discharged into the hopper *b*. In this

To the right in Fig. 7 is a plan showing the relative positions of the tower, the mixer, and the motor which operates both.

52. Concrete Elevators of Steel.

For tall buildings, elevators or towers formed of light rolled-steel shapes are often used. These are made in units of a given height which are connected to each other by means of bolts. After the building is completed the tower can be taken apart and the units stored for future use.

The initial cost of a steel tower exceeds that of a wooden one, but it has the advantage of being available for repeated use with very little ex-

illustration at *c* is shown the device that controls the discharge of the concrete from the hopper *b*, through the outlet *d*.

The mixers are sometimes placed immediately adjoining the tower on a platform that is elevated sufficiently above the grade

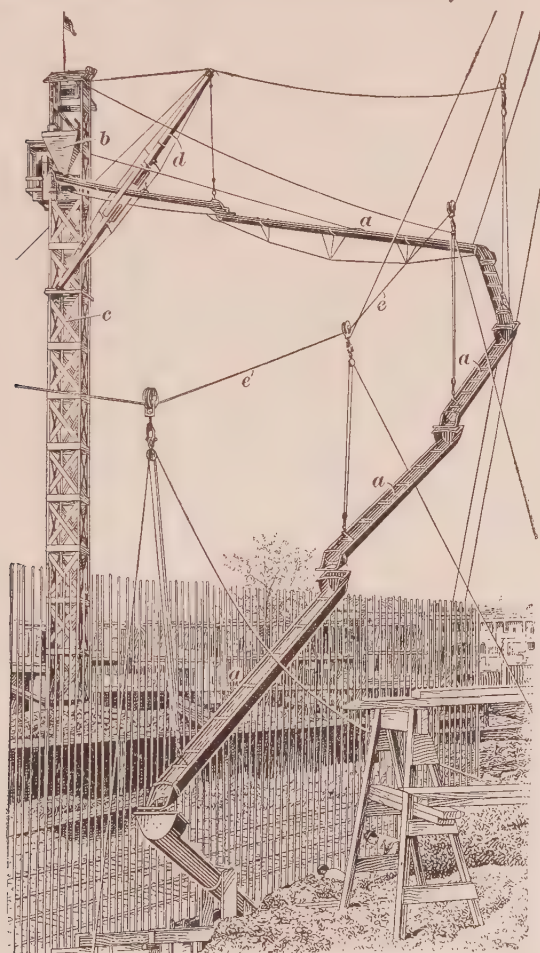


FIG. 10

level to allow the concrete from the mixer to fall into the bucket, which rests on the soil. In this method of handling the concrete, inclined runways are required between the sup-

plies of cement, sand, and stone, and the mixer, up which these ingredients must be wheeled or carted. Towers are sometimes located in a pit or in an excavated space. In such cases the mixer is placed at or below the soil level and the materials are dumped into it through a chute as shown in Fig. 7.

54. Spouting and Chutes. — *Spouting* consists of trough-shaped or pipe-shaped *chutes* *a*, Fig. 10. At the upper end, these chutes receive the concrete directly from the hopper *b*, which is attached to the tower *c* as has been described. The chutes are supported by means of booms *d*, on tripods, on cables *e*, or on brackets, as may be convenient. They are held in a sloping position so that the concrete will flow down them and be delivered at any desired point. The system of chutes is very flexible and the concrete can be delivered at any point around the tower within the distance reached by the end of the chute. This distance depends upon the number of sections of chute used and the height of the tower. The sections are from 10 feet to 50 feet in length and several sections can be used if necessary. Fig. 10 shows the use of seven sections, and illustrates the methods of using the chutes.

DEPOSITING CONCRETE

55. Separation of Ingredients.—In hauling concrete a long distance in cars or carts the vibration of the cars has a tendency to cause the coarse aggregates to settle at the bottom of the mass of concrete so that if it is deposited directly from the car the aggregates will occur in one part of the form and the mortar in another. This separation of the ingredients makes the concrete unsatisfactory. In dropping concrete from a considerable height, the stones have a tendency to separate from the mortar, which causes an unequal distribution of materials in the forms.

56. There are two important means that can be used to counteract these effects. One is to mix the concrete so as to make a stiff mixture in which the stones will not settle readily.

The second is to have the concrete dumped on a mixing board from which it is shoveled into the form. This latter method will remix the concrete just before it enters the form and thus insure satisfactory results.

In dropping concrete into a tall form, such as a form for a column or pier, it is a bad practice to dump the concrete directly from a barrow or cart into the form. The proper method is to shovel it carefully in. If the ingredients are somewhat separated in each shovelful, the mass will not be seriously affected.

The concrete should be sliced after being deposited in the forms, as will be described later. This treatment of the concrete after placing it in the forms helps to make it more uniform and compact.

57. Depositing From Spouting Systems.—When the spouting system is used to convey concrete for flat floor construction, it is the usual practice to discharge the concrete directly on the wooden forms and distribute it over a given area by means of rakes or hoes. If this method is used, the spout should be used to supply concrete for an area of about 300 or 400 square feet at one time and then moved to supply the next adjacent space. When an attempt is made to cover larger areas than this with the chute discharging in one spot, the concrete will have to be drawn through too great a distance with the rakes or hoes and will also tend to pile up too high under the chute. In such cases the liquid part of the concrete, consisting of water and cement, is apt to run out of the concrete and lodge in the lower parts of the adjacent beam and column forms. This liquid when it becomes hard forms a chalk-like substance that is called *laitance*. This *laitance* possesses little strength and the drainage of this liquid from the concrete leaves a mixture without the elements which are necessary to bind the aggregates together and which are essential to the formation of the concrete.

58. Methods of Depositing.—To secure the best construction, the concrete should be deposited in a continuous operation until an entire floor is completed. This is not always possible, however, and the method of procedure that is fre-

quently followed is to cast the columns first and then cast the floor construction in sections. In this method the concrete is placed in the column forms to the height of the under side of the beam forms, the remaining part of the column and the beams being cast with the floor. In casting the floor, joints in the slabs are usually made midway between the beams where the one pouring is to cease; in the beams, midway between the girders; and in the girders, midway between the columns. These joints are formed by placing stop boards temporarily in the positions desired to prevent the concrete from flowing beyond these places. When ready to pour the next section, these boards are removed. In this method it is necessary to start each new section before the concrete of the preceding section has become hard, otherwise there will be no bond between the sections.

59. Handling.—The concrete mixture which is placed in the forms needs but little handling in order to fill the form, but what little handling is needed is indispensable in order to drive out the air which would otherwise be trapped in the concrete and produce voids. The purpose in all concrete work is to have the concrete as dense and compact as possible, and this is obtained only by eliminating the voids.

The air pockets often form rather large voids. There is, however, another kind of voids, which are very small and appear mostly at the surface of the concrete where it is in contact with the forms; these voids are caused by a local surplus of water which assembles in small globules and, upon evaporation, leaves empty spaces. Other very unsightly voids in the face of the work are those known as stone pockets; these occur where the mixture was imperfect to begin with or became imperfect through separation of the coarser aggregates from the mortar.

60. Slicing.—For the reasons mentioned, the manipulation of the concrete in the forms is a necessity. The most commonly used tool for this purpose is the *slice bar*, or spade, shown in Fig. 11, which is used as shown in Fig. 12. By inserting the blade between the forms and the concrete and pressing

the coarse particles back into the body of the concrete, a dense skin of mortar is obtained at the surface. By working the



FIG. 11

blade up and down in the mass of plastic concrete in the forms, the air is driven out. By these two methods the concrete is made to lodge in the forms in a dense and well-packed mass.

In some cases it may be impossible, owing to the complicated forms, or other obstructions, to slice and work the concrete properly. In such cases, it is necessary to pound the outside of the forms with heavy wooden mallets, which has the effect of shaking the concrete down and giving the air an opportunity to escape.

61. Wetting.—Since water is such a necessary part of the concrete and since without it the cement cannot harden, it becomes very necessary to guard the concrete against drying too rapidly, especially in summer. Concrete contained within forms is not affected under ordinary conditions, but the surfaces of floors and pavements present such a large area to the rays of the sun that the concrete is affected unfavorably. The remedy is to cover the concrete with boards, straw, or moist earth and to keep the concrete and its covering wet by sprinkling for several days after it is laid.

62. In Freezing Weather.—Concrete that is deposited in cold weather requires to be protected against freezing. A floor or sidewalk construction is usually covered with a heavy tarred paper on which is placed a quantity of hay or straw, and boards laid on this to hold it in place. Canvas is sometimes used to form a covering over a floor and is supported on a framework of wood. This framework is made sufficiently high

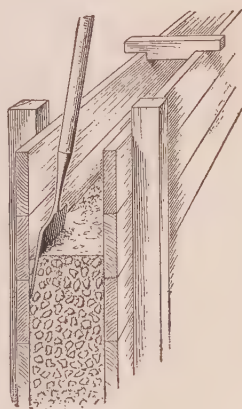


FIG. 12

so that salamanders may be placed beneath the canvas and fires be kept burning so as to maintain a temperature that will be above the freezing point. In addition to this protection for the floor construction, the sides and ends of a building are often enclosed with large sheets of canvas, and salamanders are placed in the story below the newly formed concrete floor. This method of heating produces a warmth under the floor construction and facilitates the setting of the cement in the concrete floor, beams, girders, and columns.

While concrete which has been frozen will usually harden in a satisfactory manner after thawing out, repeated freezing and thawing will injure it.

Another danger is that frozen concrete may be mistaken for hardened and seasoned concrete and the forms removed before the concrete is sufficiently strong to be self-supporting. To determine whether concrete is frozen or hardened, pour a quantity of hot water upon the concrete and if the concrete remains hard, it has set, but if it softens, it is frozen.

PLAIN, OR MASS, CONCRETE

63. Definition.—By **plain**, or **mass**, concrete is meant concrete in which reinforcing steel is not employed. It is used in the more bulky or massive parts of a structure such as the footings and foundation walls of buildings, and in retaining walls. Mass concrete is poured into prepared forms or molds and is allowed to harden, after which the forms are removed. Mass concrete is also used in making sidewalks, pavements, and floors.

APPLICATION OF PLAIN CONCRETE

64. Footings.—The footings used in building work may be considered under two divisions, namely, *column* or *pier footings*, and *wall footings*.

65. Column Footings.—Column or pier footings are placed under columns or piers and support a single concentrated load.

The simplest type of column footing, shown in Fig. 13, consists of a single layer of concrete *a*. Upon this layer a pier *b* may rest directly as shown. The thickness *d* of the footing is determined by the amount of projection *c*, and should be one and three-quarters to twice the distance *c*. If the projection is made greater than these amounts it may break off when the load is applied on the pier.

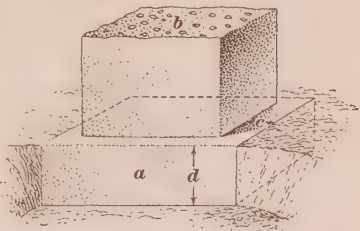


FIG. 13

66. Stepped Footings.

Where a greater projection of the footing is required, which will be the case when the load is to be greater or where the supporting soil is soft, the thickness of the footing must be

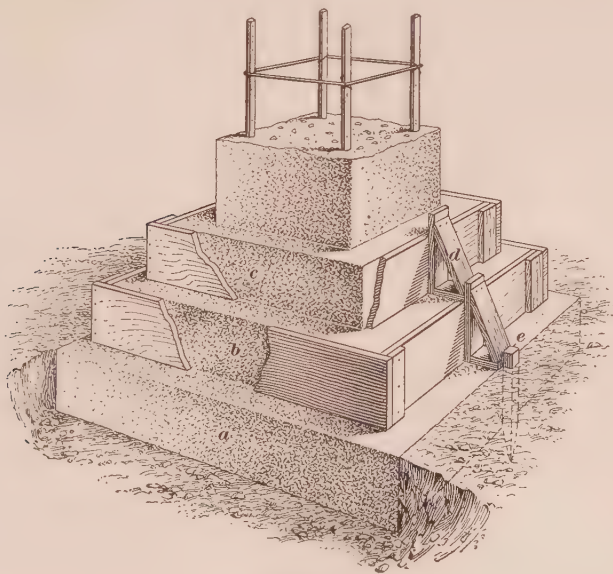


FIG. 14

increased. Instead of building the footing in a single cube-like mass, it may be made, as illustrated in Fig. 14, in steps, thereby saving considerable concrete. The concrete omitted

from above the steps does not detract from the strength of the footing. The footing shown in Fig. 14 is formed of three steps, each of which is cast separately. The lowest step *a* is cast in a mold or form made by digging a rectangular hole in the ground and filling it with concrete. The second step *b* is next cast in a wooden form, as is also the step *c*.

The forms for these steps are shown broken away, to illustrate their shape and the method of using them.

67. Tapered Footings.—In Fig. 15 is shown a tapered footing *a*, which for the same size of top and bottom surfaces

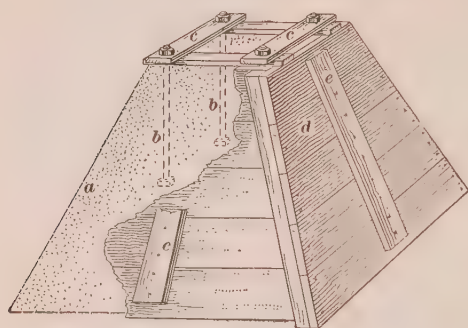


FIG. 15

and the same height is just as strong as the type shown in Fig. 14.

68. Footings for Steel Columns.

Where steel columns are to stand upon concrete footings it is necessary that they be securely bolted or anchored to the footing. This is done, as shown in Fig. 15, by means of steel bolts *b* which are embedded in the concrete and project above the top surface of the footing and through the bottom plate of the column, thus making a strong connection. The bolts must be accurately set in the concrete in such positions that when the column is set on the footing they will enter the holes in the column and can be secured by nuts. The bolts are located accurately and kept in place while the concrete is being poured, by use of a wooden templet, or pattern, *c*, in which holes are bored at proper points to receive and hold the bolts, and this templet is securely fastened to the top of the form *d* in which the footing is cast. The position of the footing and templet must be very carefully located, and they must be set true as regards the lines and levels which regulate the positions and the levels of the under sides of the column bases.

69. Wall Footings.—A concrete wall footing is a layer of concrete which is placed on the soil for the wall to rest upon. The thickness of the footing depends upon the distance that it projects beyond the face of the wall, and is determined by the same rule as that given for column footings. Concrete footings are often used for walls that are constructed of other materials, such as stone or brick, as well as for concrete walls.

An example of the use of a concrete footing for a concrete foundation wall of a dwelling house is shown at *a* in Fig. 16.

70. Plain - Concrete Walls. — Plain - concrete foundation walls of buildings are usually buried underground for their greater part, and the portion below ground needs no special ornamental surface treatment. The portion of the foundation wall above ground, also the walls of the superstructure, when formed of concrete is generally given an ornamental surface treatment.

71. In Fig. 16 is shown a section through a plain-concrete cellar wall. This wall stands on a simple footing course *a*, and the part of the wall below the surface of the ground is shown at *b*. The part of the wall above the ground contains the windows that give light to the cellar, and above the window shown is formed a concrete lintel that is reinforced by means of the steel bars shown in section

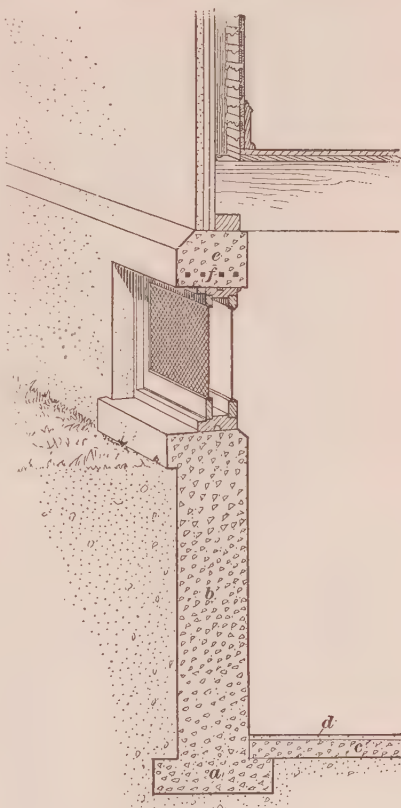


FIG. 16

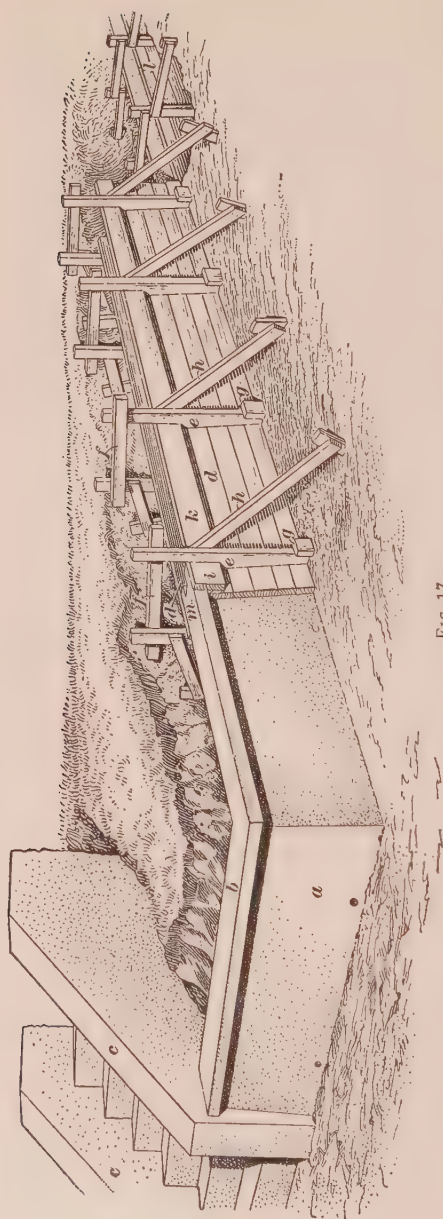


FIG. 17

at *f*. A cellar floor of concrete is shown at *c* and the finished wearing surface of the floor at *d*.

72. Retaining Walls. — Another use for plain or mass concrete is in building *retaining walls*. An example of a retaining wall which serves to hold up a small terrace is given in Fig. 17. At *a* is shown the finished wall; at *b*, a coping which projects beyond the face of the wall to shed rain, as well as to form a finish for the wall. A similar wall without coping is shown at *c* on each side of the steps.

73. A cross-section of this retaining wall is indicated in Fig. 18, the part above ground and the outline of the terrace back of the wall being shown dotted. Behind the wall, just below the coping *d*, is shown a gutter *e*, which serves to catch

the water that flows down the terrace and lead it away so that it will not seep down back of the wall. Any water that does

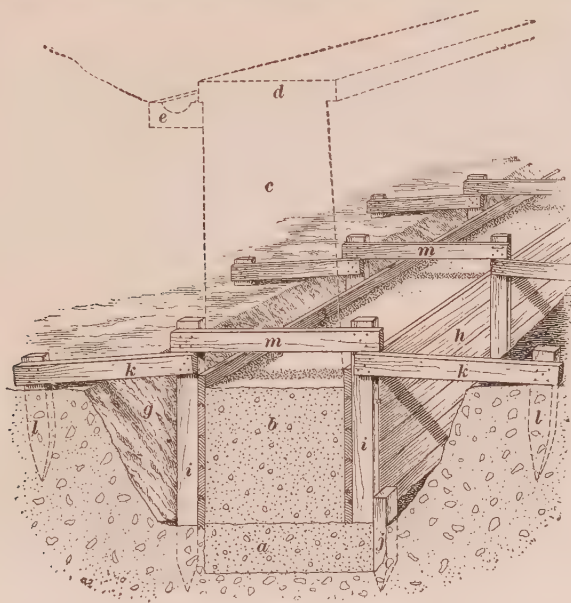


FIG. 18

penetrate the earth behind the wall can escape through the pipe-like holes formed in the wall just above the grade, as shown in the wall *a* in Fig. 17.

After the wall has been completed the soil is filled in back of the wall as indicated by the dotted outline in Fig. 18. The part filled in is sometimes called the *back fill*.

FORMS FOR PLAIN CONCRETE

74. Forms for Footings. — A form is not usually required for the construction of a footing such as is shown in Fig. 13, as a space the exact size of the footing can generally be excavated in the soil and filled with concrete. When, however, as in gravel or sand, the sides of the excavation will not remain vertical, wooden forms are used. A form for a footing such as shown in Fig. 13 may be made of four boards cut to

the required lengths and nailed together in the form of a box. Stakes, driven in the ground outside such a form, hold it in place and prevent the sides from bulging when the concrete is poured into it.

75. The form for a footing such as shown in Fig. 14 is made in sections. If possible, the form for the lowest part of the footing *a* is made in the soil without the use of wood. If the sides of the excavation will not stand up, board forms must be used for this section. In either case forms must be provided for the sections *b* and *c* somewhat as shown in the figure. These forms are held in position by braces *d*, which are fastened to the stakes *e* and to the forms.

76. A part of a form for a tapered footing is shown at *d* in Fig. 15. This form is made of planks having their ends cut to a bevel as required by the shape of the footing. The planks of each side are held together by means of battens *e* and the sides of the frame are also nailed together at the corners. Interior cross-braces are sometimes used to preserve the shape of the form until it is set in place, after which they are loosened and removed through the open top of the form before the concrete is poured.

77. Forms for Piers. — Fig. 19 illustrates several methods of making forms for piers. The four sides are built of planks running vertically. These sides are held together by the different devices shown. In all these, iron or steel bolts are employed, and wooden wedges are freely used to bring the various parts tightly together. In the lower right-hand illustration is shown the use of angle irons fitted to the corners of the form and drawn together by means of bolts.

The main object of these pier forms is that they shall confine the mass of concrete so that it will not move or spread out the sides of the forms, and that the finer parts of the concrete will not leak out. They are also made so that they can easily be taken down and used as forms for other columns. Further reference to forms for piers and columns will be made later. Other designs for forms will also be shown under the heading Reinforced Concrete.

78. Forms for Walls.—The forms used in the construction of a low retaining wall of plain, or mass, concrete are

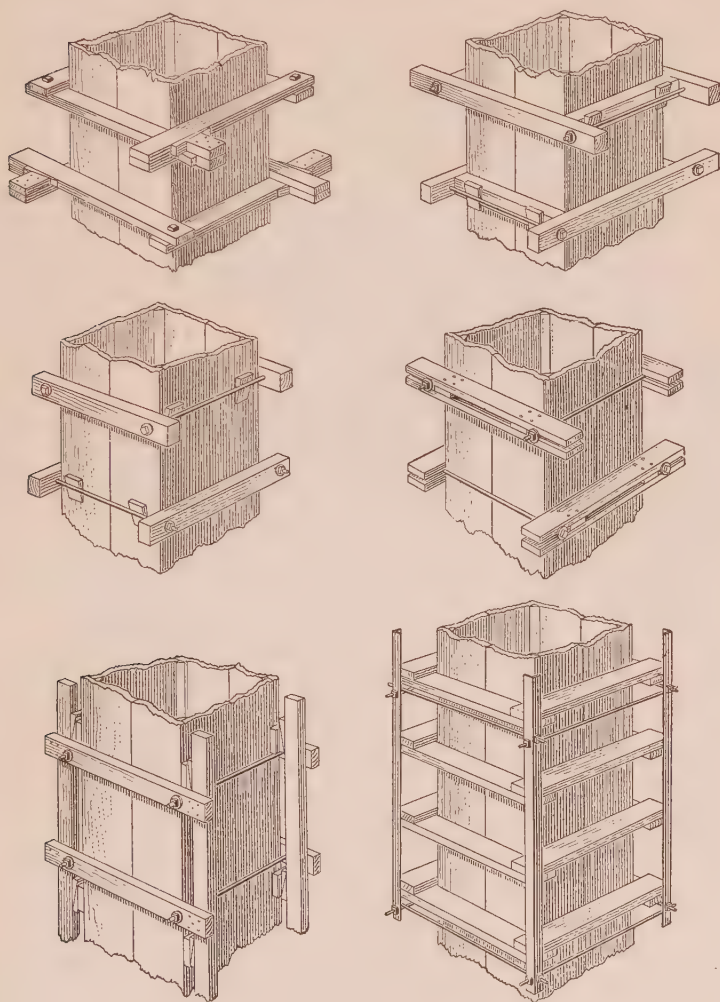


FIG. 19

shown in Fig. 17. The wall is indicated in cross-section in Fig. 18, in which *a* is the footing, *b* the wall below ground, *c* the wall above ground, and *d* the coping member.

The footing *a* is poured first, the earth being excavated to act as a form. Large-sized stones are sometimes placed in the footing and extend above its surface so as to tie the footing to the section *b*.

The excavation for the wall, as a whole, should be made of sufficient size to permit workmen to set the forms required for the portions of the wall above the footings.

The section *b* is cast in forms that are constructed as shown. The boards *h* are nailed to the uprights *i* and these are then set in place. They are held in the proper position by stakes *j*

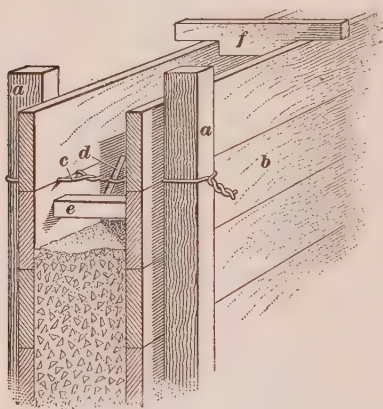


FIG. 20

driven into the ground and by braces *k* that are nailed to them and to the stakes *l* driven at convenient points in the adjacent bank.

Spacers *m* nailed to the uprights *i* keep the two faces of the form at the correct distance apart.

79. When the lower section of the whole wall has been finished and has had time to set, the form work is removed and the earth is shoveled and tamped into place against the wall and the forms are set for the top section of the wall as shown in Fig. 17.

80. The form used for this section of the wall consists of planks *d*, fastened to posts, or battens, *c*. The battens are held in place at the top by the spacers *f* and at the bottom by the stakes *g*, which are driven into the ground. They are further braced by the inclined braces *h*. The form is constructed to allow for the coping as shown at *i*, the battens being cut in the shape shown and the board *k* nailed outside of the lower boards *d*, thus providing for this projection.

81. Another type of wall form, for comparatively thin walls of considerable height, is shown in Fig. 20. The battens *a*, which support the planks *b*, are held together by means

of wires *c* that pass between the planks and are twisted by means of sticks *d* and tend to pull the forms together. To prevent their being pulled together too closely, spreaders *e* are placed close to the wires. These spreaders are removed as the concrete reaches their levels, as they are no longer needed, the concrete being sufficient to keep the forms apart. Spacers *f* are also used at the tops of the forms to keep the forms the proper distance apart.

After completion of the concrete work, the wire ties are cut and the forms removed, and the projecting ends of the wire ties are then dressed back as closely to the face of the wall as

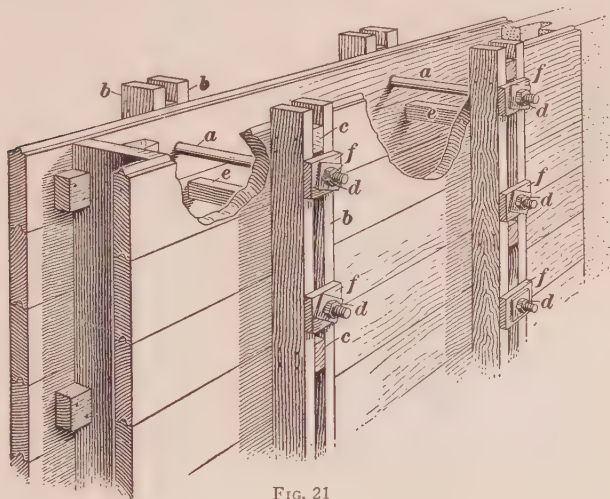


FIG. 21

possible. They will, however, rust in time and stain the walls, therefore methods that permit of the iron ties being removed entirely are preferable for work that will be seen.

82. A method by which the forms are held together by bolts instead of by wire ties is illustrated in Fig. 21. Here bolts *a* extend through battens, or posts, formed of two pieces *b* kept about 1 inch apart by means of blocks *c* nailed between them. On the ends of the bolts are applied iron washers and nuts *d* by which the battens are firmly held. The bolts are made of sufficient length to serve for the thickest walls that

are to occur in the building, and when they are used for thinner walls the difference in thickness is taken up by means of blocks of wood *f*. Wooden *spreaders* *e* are used to keep the sides of the form apart and are removed when the concrete reaches their levels. As soon as the wall has set and the forms have been removed, the bolts are withdrawn. There will then be no iron left in the wall to cause rust stains.

83. Steel Forms.—There are on the market many patented types of metal forms for concrete wall construction.

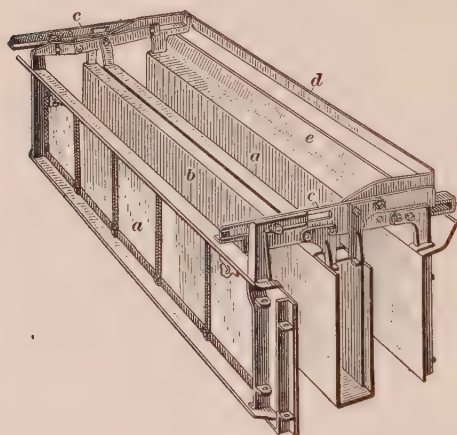


FIG. 22

One class consists of small units and provides for the casting of only a small amount of concrete at one time. Forms of this class are generally used for the construction of the walls of houses and other small structures. The concrete is mixed quite dry, the forms are filled by hand and the concrete thoroughly tamped to se-

cure a compact mass. Immediately after this is accomplished, the form is removed, placed elsewhere, and another section of wall is cast.

Another class of steel forms, which may consist of small or of large units, provides for casting a large quantity of concrete at one time and is used where large masses of concrete are to be placed. The concrete is poured into the forms, which are left in place until the concrete has hardened, after which they can be removed and used for building other parts of the wall.

84. In Fig. 22 is shown an example of a metal form for casting a hollow concrete wall. It consists of the outside plates *a*, and the partition *b*, which forms the space between the

outer and inner parts of the wall. The cross-bars *c* are adjustable and allow of making the outer and the inner shells of the wall of different thicknesses. The flanges *e* are spread so as to prevent pouring the concrete over the outside of the form. At *d* is shown a handle which can be raised to a vertical position and is used to lift the entire form so as to remove it from the wall.

85. In Fig. 23 is shown a portion of a concrete wall in the process of construction by use of the form just described. At *a* is the outer shell of the wall, at *b* is the steel form in position



FIG. 23

and being filled with concrete. Recesses *c* are shown in the wall to receive the floor joists. These recesses are formed as shown at *d* by inserting temporary wooden blocks in the proper positions when filling the steel form. At *e* is shown one of these temporary blocks partly removed. Wooden strips *f* to be used as nailing pieces to which woodwork can be secured can be placed in the mold at any desired point.

86. Fig. 24 shows a portion of a completed wall *a*. The form *b* has just been raised and is about to be placed on the

wall to form a new section. It will be placed so as to cover the sloping end of the part just completed. A course the depth of

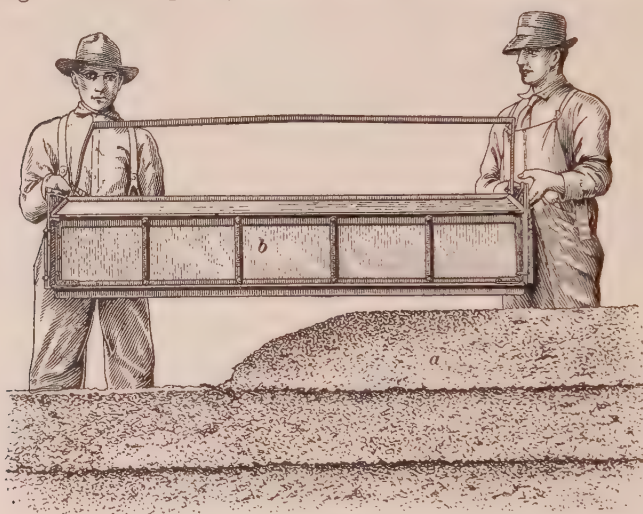


FIG. 24

the machine is cast around the building. By the time this is done the portion of the course that was cast first will be hard

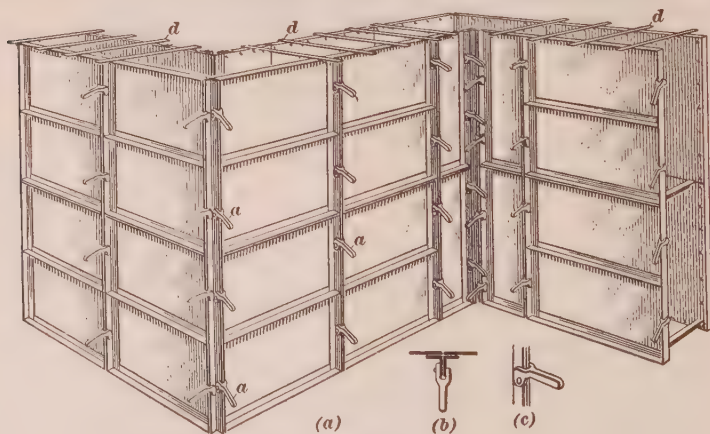


FIG. 25

enough to receive a new course on top of it. This course is carried around the building in the same manner.

87. Fig. 25 shows a form consisting of units made of galvanized sheet iron with angle-iron frames, which are assembled, locked together, tied, and braced in such a manner that they are rigid and sufficiently strong to resist the pressure of concrete in large masses. They are fastened together by the clamps *a*, which when raised up as shown cover the angles of the two adjacent units and hold them together. The clamp

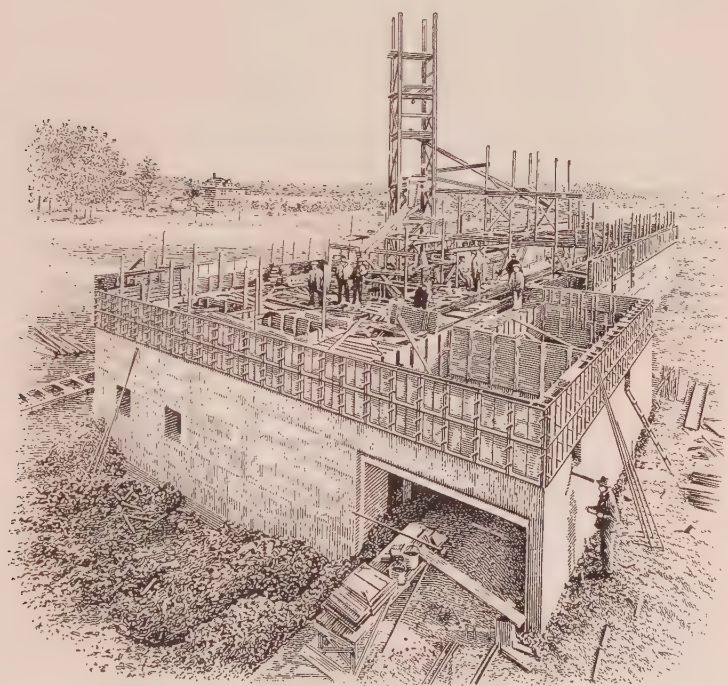


FIG. 26

is shown separately at *b*, where the observer is looking down upon it, and at *c*, which is a perspective view. The rods *d* are called *stay-rods* and are adjustable to hold the plates at the proper distance apart. The smooth surface of the galvanized iron gives a smooth finish to the surface of the wall. In Fig. 26 is shown a building in process of construction in which this type of sheet-metal form is being used

88. Forms constructed of pressed-steel uprights *a* are shown in Fig. 27. The forms between these uprights are made of sheets of steel stiffened by the wooden planks *b*, which are secured to the backs of the steel plates. These forms are light in weight, are easily handled, and are especially adapted to the

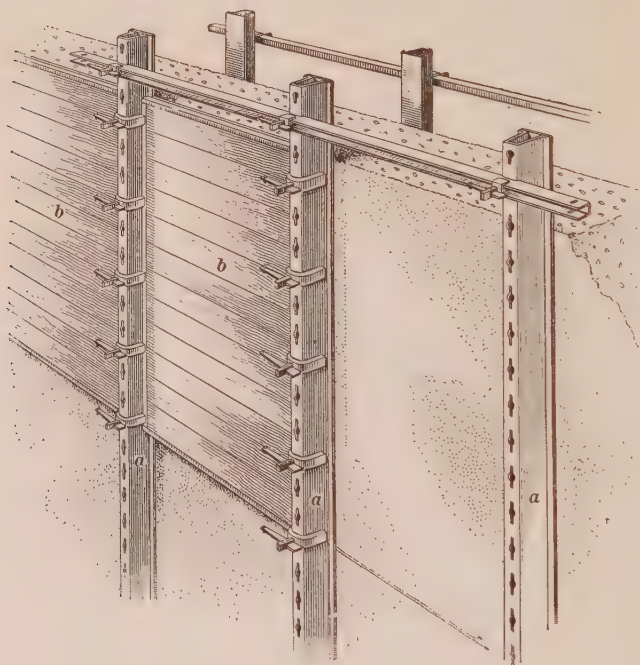


FIG. 27

construction of structures that require large masses of concrete, such as retaining walls, of which Fig. 28 is an illustration.

89. **Forms for Steps.**—Steps are built in forms such as are shown in Fig. 29, in which *a* indicates the concrete treads and platform, and *b* the boards that form the risers. The side forms, shown at *c*, consist of boards nailed to battens. These battens are held in place by the blocks and braces *d*. Special bracing is provided at *e* to prevent the riser boards from bulging when the concrete is placed in the form.

90. Expansion Joints.—Long retaining or other walls are provided with what are called *expansion joints* at intervals

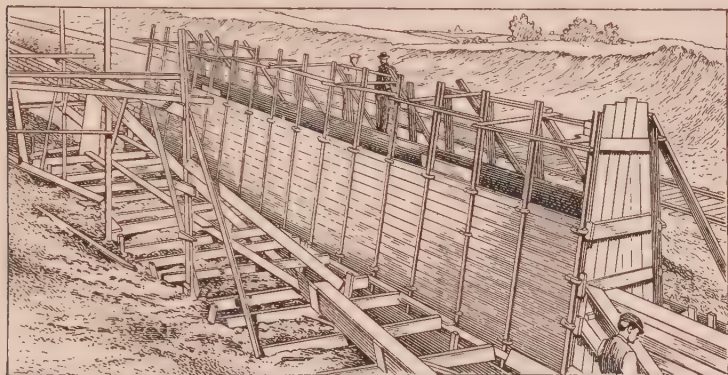


FIG. 28

of from 35 to 50 feet. These joints allow the wall to expand and contract with the change in temperature. An expansion

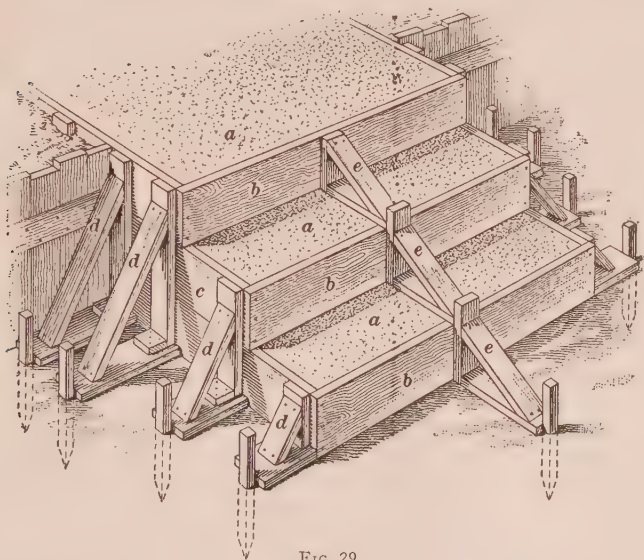


FIG. 29

joint is shown in the wall in Fig. 17 at *m* and in detail at *a* in Fig. 30. A form for such a joint is shown in Fig. 21.

In order to prevent the face of one section being pushed beyond the face of the adjacent section, the joint is formed with a tongue-and-groove construction. The end of the finished section is greased or covered with a layer of tar paper before the next section is cast against it.

91. Assembling and Removal of Forms.—Wooden forms for small structures are assembled as already described.

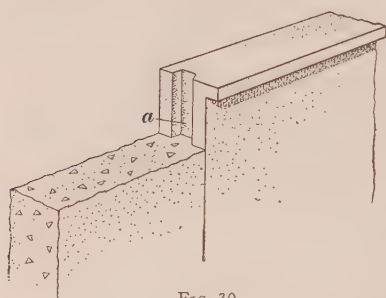


FIG. 30

Wooden forms for large structures are described later under Reinforced Concrete, as is also the removal of the forms and the care that should be taken of them to permit of their repeated use.

The manner of assembling and removing forms of the patented types depends entirely upon the character of the forms, and the manufacturers provide detailed instructions relative to the use and care of their products. Forms of this character are usually designed so that the units are interchangeable, and also adjustable, hence the forms may be used in the construction of walls of various thicknesses and heights.

SURFACE FINISHES FOR WALLS

92. Concrete, when placed, fills every irregularity of the forms, and when the forms are removed the imprints of any defects are plainly visible on the concrete. Therefore, if it is desired to have a concrete of uniform surface, the first requisite is a form without defects or blemishes of any kind. Such a form cannot be made of wood; only steel forms are sufficiently smooth to leave no marks on the concrete.

Even when steel forms have been used, there are defects in the wall surfaces where the units, which compose the forms, adjoin each other. Furthermore, concrete is not always acceptable for high-class work because the concrete itself has a dull

grayish color which is very monotonous, and when wet it becomes streaked and blotched.

93. Methods of Finishing.—There are various methods of obtaining uniform and pleasing surfaces on concrete walls. One of these consists of washing or brushing the surface before the concrete has thoroughly hardened. Another is to tool or sand-blast the surface after it has become thoroughly hardened. A third method is to apply a facing of special concrete to the form by means of a trowel and back it up with ordinary concrete. This facing can be made of white cement mixed with marble dust, special colored aggregates, etc. These methods produce agreeable and artistic results.

94. A facing material of mortar containing one part cement and two parts of fine aggregate, such as marble screenings or colored sand, is often used. Mortars for facing should never be made richer than 1 part cement and 2 parts sand or screenings. If gravel or fine stone is to be added to the cement and sand, for a facing, the mixture may be made in the proportions of $1 : 1\frac{1}{2} : 3$ or $1 : 2 : 3$. If coarse aggregate is used, the minimum thickness of the facing should be not less than twice the maximum dimension of the largest pieces of stone.

95. Surface Finishes.—Surfaces of plain concrete walls may be **brushed**. In this treatment the forms must be removed within 12 hours after the concrete is poured; then, while the surface is still comparatively soft, it is brushed with a bristle brush to remove the mortar from the surface and leave the coarse aggregate exposed. An acid wash may be applied after the brushing in order to remove the film of cement that may adhere to the stone. Such a wash should be a very weak solution of muriatic acid, and after it has been used, the acid should be carefully washed off the wall by a liberal use of clean water.

96. Rubbed Surface.—If a rubbed surface is desired, the forms are removed from the wall after the concrete is a day or two old and the surface is rubbed with a brick formed

of carborundum or emery, or with a piece of soft sandstone. A good rubbed surface is secured when the facing mixture contains little or no coarse aggregate. A thin grout composed of cement and sand should be applied during the process of rubbing and the surface afterwards washed down with clean water.



FIG. 31

97. Sand - Blasted Surface.—

A sand-blasted surface has very much the same texture and finish as that obtained by brushing. This treatment is applied, however, after the concrete has become hard. Any pronounced ridges or irregularities in the surface should be removed by tooling, and cracks or open joints should be pointed some time before the surface is sand-blasted, in order that the filling may be hard.

98. Tooled Surface.—Concrete surfaces may be finished by tooling by any of the methods and in any of the styles employed for finishing natural stone. Where a surface is to be tooled, the best results are obtained when a facing material with comparatively small-sized aggregates is used, as it is hard to dress and to obtain uniform results on surfaces when large stones are encountered. Concrete should be thoroughly hard



FIG. 32

before being tooled, especially if sharp edges and surfaces of a fine uniform texture are desired.

99. Tools.—Tools that are frequently used for surfacing concrete walls are the *bush hammer*, shown in Fig. 31, and the *concrete ax*, shown in Fig. 32. Where compressed air is avail-

able, the concrete may be dressed with a *pneumatic hammer*, which gives excellent results in the hands of an expert.

100. Examples of Surfaces.—An example of concrete facing containing an aggregate of trap rock and having a

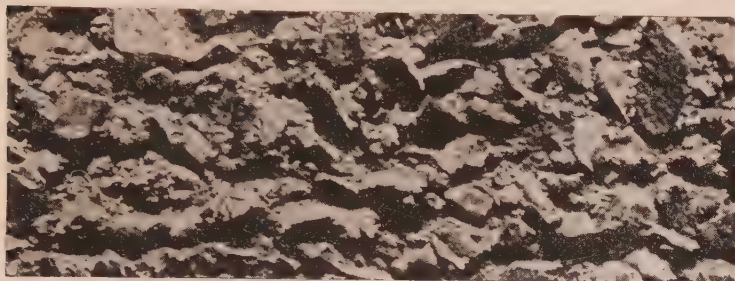


FIG. 33

brushed surface is shown in Fig. 33. A surface dressed with a pneumatic hammer is shown in Fig. 34. The effects obtained



FIG. 34

by the use of the bush hammer or the ax are about the same as those obtained with the pneumatic hammer, but are not quite so regular and uniform in texture.

REINFORCED CONCRETE

101. General Explanations. — Reinforced - concrete structures are structures built of concrete in which steel has been embedded to add tensile strength to the concrete. The amount of metal used is generally small in proportion to the amount of concrete. In this type of construction *the steel and*

the concrete are so placed and combined that either, if left alone, would sustain but a small fraction of the load which they will carry when combined. There are other forms of construction in which concrete and steel are used in combination but which are not of reinforced-concrete construction. In one form the steel carries all or practically all the load, the concrete serving merely as a protective coating. In another form the concrete carries all or nearly all the load, and the steel is used to tie parts of the structure together.

102. Uses of Reinforced Concrete in Building.

Reinforced concrete is well adapted for use in the construction of walls, beams, girders, columns, floor slabs, or other parts of the structure which carry the loads. It is also an economical material, and entire buildings are built of it, such as warehouses and factories where appearance is a secondary consideration. It is also employed in constructing buildings that are artistic, but such work is not particularly economical since these results can be obtained only by the use of expensive materials, expert workmanship, and with the greatest care in the construction. The use of reinforced concrete for artistic construction is nevertheless rapidly increasing, especially in the erection of high-class residences, schools, etc.

STRENGTH OF CONCRETE

103. In considering the strength of concrete, the forces acting in the various parts of a building that are constructed of concrete should be understood. These forces are known as *tension*, *compression*, and *shear*.

Tension is a force which tends to pull a body apart. It is resisted by the *tensile strength* of the material. *Compression* is a force that tends to crush or push together a body or mass of material. This is resisted by the *compressive strength* of the material. *Shear* is produced by two forces acting in opposite directions in a manner similar to the two blades of a pair of shears. These forces tend to push one portion of a body past another part, thus dividing it. The forces mentioned are gen-

erally the result of direct loads applied to the various columns, piers, girders, and beams.

104. In the case of steel, the compressive and tensile strengths are approximately equal. In concrete, the compressive strength is from six to ten times as great as its tensile strength. In other words, it requires from six to ten times the load or force to destroy it by compression that it does to break it by tension. The resistance of concrete to shear is also quite small.

105. The compressive strength of concrete is therefore its most important one and this can be determined by testing cubical or cylindrical specimens of the concrete. After these have been made and allowed to harden for a certain time, such

TABLE II

TABLE OF CRUSHING STRENGTH OF DIFFERENT MIXTURES OF CONCRETE, IN POUNDS PER SQUARE INCH

Aggregates	1 : 1 : 2	1 : 1½ : 3	1 : 2 : 4	1 : 2½ : 5	1 : 3 : 6
Granite, trap rock.....	3,300	2,800	2,200	1,800	1,400
Gravel, hard limestone and hard sandstone	3,000	2,500	2,000	1,600	1,300
Soft limestone and sandstone.	2,200	1,800	1,500	1,200	1,000
Cinders	800	700	600	500	400

as 28 days, they are tested in suitable machines by crushing or compression. The load or force required to crush each is noted and is then divided by the horizontal cross-section of the specimen in square inches and the number of pounds per square inch required to crush it is obtained. The crushing strength increases with the age of the concrete and with the increase in the proportion of cement used in making it.

106. In Table II the average crushing strength of various mixtures of concrete, in pounds per square inch, is given. The specimens tested were cylinders 8 inches in diameter and 16 inches long, and the age of the concrete was 28 days.

The figures here given were determined by the Joint Committee appointed by the American Society of Civil Engineers,

the American Society for Testing Materials, the American Railway Engineering Association, the Portland Cement Association, and the American Concrete Institute. This committee recommends that concrete used in construction should not be loaded more than a certain fraction of the ultimate, or crushing, strength indicated in the table. Building codes, in general, do not make the distinction between the various coarse aggregates that are given in this table nor do they give the ultimate crushing strength of the concrete. Instead, however, they give the load that is permitted, called the *safe load* per square inch, for concrete formed with different proportions of ingredients. For example, the New York Building Code contains the following:

CONCRETE IN COMPRESSION	SAFE LOAD PER SQUARE INCH
Concrete, Portland cement, 1 : 2 : 4	500 lb.
Concrete, Portland cement, 1 : 2½ : 5	400 lb.

From this it will be noted that the 500-pound load is 22.7 per cent. of the crushing load given in Table II for trap-rock concrete having the same proportions of ingredients; and the 400-pound load is 22.2 per cent. of the crushing strength of concrete of similar proportions and like material. Thus, in practice, the safe load for concrete is taken as a little more than one-fifth of the crushing strength shown in 28-day tests.

107. Advantages of Reinforced Concrete.—Reinforced concrete buildings, when properly designed and built, are very strong. They can be erected at a reasonable first cost and the cost for upkeep is low. They are therefore looked upon with favor in purely commercial enterprises.

Buildings formed of this construction are less affected by vibrations and shocks than some other types, because they are so firmly knit together that they are not easily disturbed. They are particularly adapted to regions subjected to earthquake. They have the additional advantage of being fireproof, damp-proof, and vermin-proof, thus protecting their contents from injury by fire, water, or rodents.

THEORY OF REINFORCED-CONCRETE CONSTRUCTION

108. Classes of Members.—Reinforced-concrete buildings are formed of walls, columns, piers, girders, beams, and slabs. These members may be grouped into two classes,

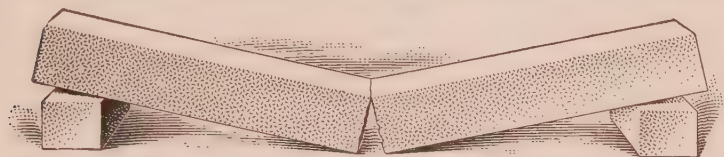


FIG. 35

namely, *columns* and *beams*. Under the heading *columns* may be placed vertical supports such as columns, piers, and walls, and under *beams* all horizontal members such as girders, beams, and floor and roof slabs.

The principles used in designing these two classes of members are very different, and will be merely illustrated in this Section, but will be more fully discussed in the Sections *Design of Columns* and *Design of Beams*.

109. Beams.—All the horizontal members of a structure, such as girders, beams, and floor slabs, are virtually beams. The stresses acting in loaded beams can be shown by experiment. Thus, if, as shown in Fig. 35, a concrete beam, without steel reinforcement is loaded until it fails, or breaks, it will in all probability break as shown in this figure. The lower portion will be pulled apart due to limited tensile strength of concrete.

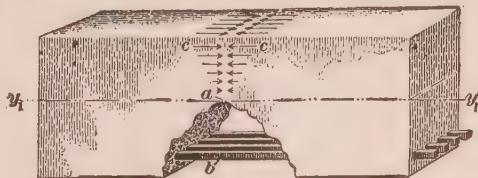


FIG. 36

110. Now if a sufficient number of steel rods are introduced near the lower surface of the beam, as shown at *b* in Fig. 36, the tendency to pull apart in its lower portion, when the beam is loaded, will be overcome. The effect of a load on

a beam is to produce compression in the upper portion of the beam as indicated by the arrows c , and tension in the lower por-

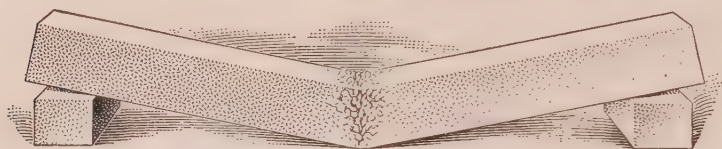


FIG. 37

tion, which is neutralized by the steel rods. The concrete has considerable compressive strength and resists strongly any tendency to crush it. In a well-designed beam, the crushing strength of the beam above the line $y_1 y_1$ will be balanced by the tensile strength of the steel below the same line.

111. If there is more tensile strength provided in the steel reinforcement than there is crushing strength in the concrete, and the beam is loaded until it breaks, it will fail by crushing at the top, as illustrated in Fig. 37. It will require, however, a much greater load to break the beam in this case than in the case shown in Fig. 35, thus demonstrating that the reinforcement adds much to the strength of the beam.

The designing of reinforced-concrete beams consists of supplying the proper proportion of reinforcing steel and concrete so that under a maximum load, the steel will not fail by tension before the concrete fails by compression, and vice versa.

112. When the concrete and the steel are under about the same stress, the beam, if heavily loaded, will sometimes stretch

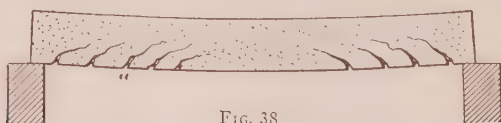


FIG. 38

the steel excessively and the concrete will develop small cracks such as shown at a in Fig. 38.

113. Columns.—In columns, reinforcement is not absolutely necessary, as concrete is strong in compression. It is,

nevertheless, good practice to use reinforcement, because the steel makes the column safer to use and also increases its carrying capacity. A smaller reinforced column will therefore do the work of a larger one not reinforced and will occupy less space. This reduction in size is due to the fact that the strength of the steel rods encased in concrete in resisting compression is very great. Even a small amount of steel thus embedded will support a considerable load and permit of a reduction in the concrete area required. The arrangement of reinforcement in columns will be shown later on.

114. Design of Reinforced-Concrete Buildings.

The complete computations required for the design of reinforced-concrete beams and columns are complicated and the architect therefore usually entrusts this part of the work to engineers who have made a specialty of reinforced-concrete work. It is, nevertheless, important for the architect to know the principles involved in the design so that he can arrange the architectural features of a building harmoniously with the engineering features, and also so that he can tell in the field whether or not the principles of good construction are faithfully followed. For this reason, the following articles will be devoted to a brief description of the best types of reinforced-concrete building construction and the principles upon which these types are based.

In making the preliminary plans, the architect should make provision for columns having a somewhat larger area than for steel columns that carry equal loads. He should also provide in the height of the stories for the greater depth of beams and girders that are required in reinforced-concrete construction.

REINFORCEMENT

REINFORCING MATERIALS

115. Quality of Steel.—Steel selected for reinforced concrete should be of a quality that is suitable for this purpose. It may be advisable in small structures to obtain the steel from a local stock, even though the quality of the steel is not the best; for large structures, however, the quality of steel desired is usually specified and the order is filled at the rolling mill, or it may be taken from stock that has been proved by tests to conform to the specified requirements.

116. The specifications generally followed in describing reinforcing steel are those of the American Society for Testing Materials, which recognizes two different kinds of steel, namely, *billet steel* and *rerolled steel*. **Billet steel** is made from new billets or blocks which are rolled out to the required shape. There are three varieties of this steel, known as *structural*, *intermediate*, and *hard* steel. **Rerolled steel** is made from old railroad rails that are split and heated and passed through rolls in order to form them into the proper shape. There is only one grade of rerolled steel and it has properties similar to those of the hard grade of billet steel. Owing to its brittleness, which is especially pronounced in frosty weather, hard steel and rerolled steel are adapted only for structures that are not subject to shocks or vibrations and in which the rods or bars do not require much bending.

Specifications for reinforcing steel frequently require that samples be taken from the various shipments of steel, after they have been received at the building site, and tested to prove that the steel is of the quality required. This is done by employes of a testing laboratory.

117. Allowable Stress in Steel.—Steel is considered as being able to sustain safely a tensile force of 16,000 pounds per square inch. The safe compressive strength of steel is taken to be 10,000 pounds per square inch.

This compressive strength of steel is about 15 times the safe compressive strength of concrete, which is considered to be from 650 to 750 pounds per square inch.

118. Forms of Reinforcement.—Steel reinforcement for concrete construction may be in the form of loose rods or bars, rods or bars that have been secured together into shapes known as *units*, sheet metal which has been expanded into what is known as *expanded metal*, and wires that have been woven or welded together to form what is known as a *fabric*.

The loose rods or bars may be used as a reinforcement in any of the structural parts of the building. The units are used only in the beams, girders, and column construction; and the expanded metal, perforated metal, and fabrics, in the wall and floor construction. The forms of these reinforcing members are described later on in this Section.

BARS AND RODS

119. Forms of Bars.—Steel bars and rods for reinforcing concrete may be either plain or deformed. Plain bars are

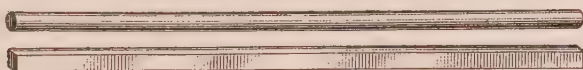


FIG. 39

round or square, as shown in Fig. 39. Deformed bars are twisted or provided with projections and depressions for the purpose of increasing the adhesion of the concrete to the bar. Deformed bars are illustrated in Figs. 40, 41, and 42. The terms bar and rod are used interchangeably and may apply to round or square bars, either plain or deformed.

Many buildings in this country have been built with plain bars and practically all

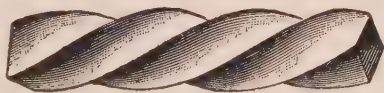


FIG. 40

work done in foreign countries has been erected with plain bars only. Most American engineers, however, prefer the deformed

bars as offering additional safety at a very small increase in cost.

120. Adhesion Between Concrete and Steel.—A steel bar embedded in concrete offers considerable resistance to being pulled out. This resistance is due to the adhesion between the concrete and the bar. The adhesion of the con-

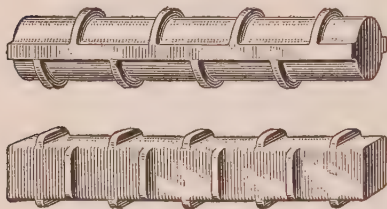


FIG. 41

crete to steel bars is naturally increased by deforming the bar, and a smaller deformed bar will do more work than a larger plain bar.

121. To test the adhesion between steel bars and concrete, specimens such as shown in Fig. 43 are prepared, consisting of a block of concrete in which a steel bar of the kind to be tested is embedded, with one end projecting as shown. The test consists in pulling the bar out of the concrete block and noting the force required to do so. If, in testing different kinds of bars, two bars of equal diameters and equal lengths of embedment show different resistances against efforts to pull them out, the conclusion is naturally drawn that the bar requiring the greatest pull adheres best to the concrete and is therefore the one to be preferred in practice.

Many tests of the kind described have been made and have showed that the adhesion is greatest when a rich mixture of concrete is used; that the adhesion is greatly increased when care is used in preparing and storing the specimens and especially when the concrete is kept moist during its hardening period so as to furnish sufficient water for the cement to set properly; and



FIG. 42

that it is very important that the bars be embedded in large blocks. Therefore, in actual construction the concrete should be properly proportioned, carefully placed, and kept moist until hard, in order to develop the greatest adhesion; and also

the bars must be kept away from the immediate surface of the concrete member in which they are embedded.

122. Deformed Bars.—Of the many deformed bars obtainable in the market, only a few will be mentioned as typical of various designs.

The **Ransome bar**, Fig. 40, is made by twisting a plain square bar in a cold state. The sliding resistance of the bar is increased by the spiral ridges along the surface of the bar. These bars are made of soft steel, are easily bent on the job, and make good reinforcement.

123. Hot-twisted bars are rerolled bars twisted in a hot state. They are usually very hard and very brittle and should not be used without careful testing to insure the quality. They may be recognized by being covered by so-called *mill scale*, which is a metallic coating formed in scales upon the surface of all bars when they leave the mill. This mill scale drops off the cold-twisted bars in the twisting process.

124. Corrugated bars are shown in Fig. 41. These bars are formed with projections on all sides which extend into the surrounding concrete and obtain a firm grip.

125. Havemeyer bars are made round, square, and I beam in shape. They have longitudinally extending fins or projections giving the bar a wavy outline in profile. In Fig. 42 is shown a round bar of this design.

126. Trussed bars, also known as *Kahn bars*, are made from bars having at two opposite sides flat extensions as shown in Fig. 44 at *a*. These extensions are sheared along part of

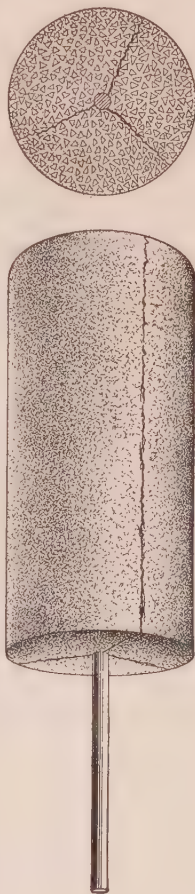


FIG. 43

their length so as to separate them from the body of the bar for considerable lengths, only short spaces of connection being left at intervals. The sheared portions *b* are bent to form

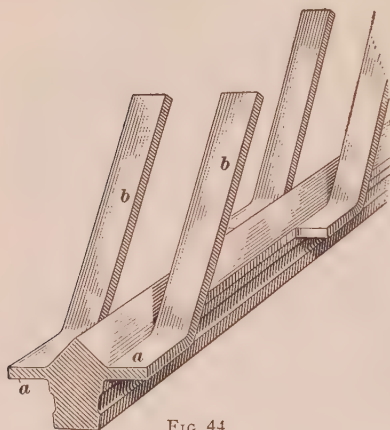


FIG. 44

prongs or projecting parts as indicated in Fig. 45. These projecting parts serve to increase the adhesion of the bar to the concrete, and also act as reinforcement of the concrete, to resist the action of shear.

There are many other kinds of deformed bars on the market all of which possess some particular point in their favor.

127. Units.—Bars intended for the reinforcement of beams and girders are sometimes assembled at the mill in the form of frames called **units**. The advantage of forming the reinforcement into a



FIG. 45

unit at the mill is that the various bars are properly placed and held in position more accurately than they might be if built at the building. The bars are fastened together and when set in



FIG. 46

the form they are all in the proper relation to one another and in such a position that they will be most effective in resisting the various stresses in the beam or girder. An example of a unit designed for use in a girder is shown in Fig. 46.

128. Spirals.—For columns, reinforcement in the form of spirals or hoops such as shown in Fig. 47 (a) is also made at the mill in a *unit*, consisting of the spiral stiffened by the vertical members *a*.

129. Both the units for girders and the spirals for columns are frequently made so that they can be folded flat for convenience in shipping. When they are to be used in the building they are expanded to their proper shape and set in the forms. A collapsible spiral reinforcement unit for a column is shown in Fig. 47. In (a) is the expanded unit, in (b) is a view of the unit collapsed, and in (c), a side view of the collapsed unit.

EXPANDED METAL

130. The form of sheet-metal reinforcement known as **expanded metal** is shown in Fig. 48. This material is made in sheets of short lengths that are easily put in place. They must be lapped, however, wherever they meet. The meshes, or diamonds, are formed in different sizes and the metal is made in different thicknesses according

to the purpose for which the reinforcement is to be used. The 3"×8" mesh, or opening, is commonly used in reinforcing floors in buildings and the 6"×12" mesh is used for sidewalks. The manufacturers' catalogs give the various thicknesses, mesh sizes, and strengths of the different patterns of expanded metal when used for different floor spans and with various mixtures of concrete.

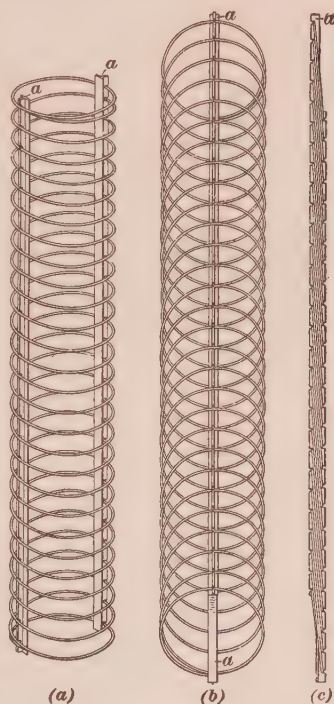


FIG. 47

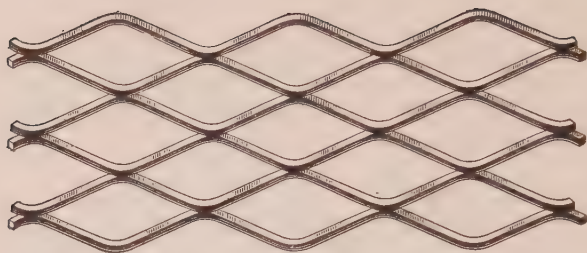


FIG. 48

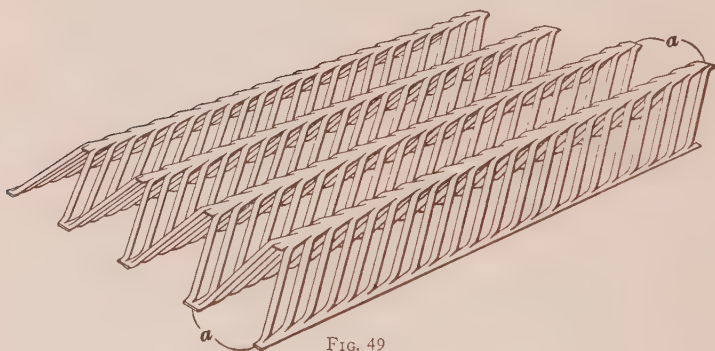


FIG. 49

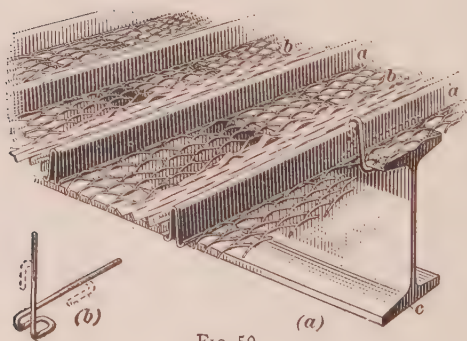


FIG. 50

In laying out expanded-metal reinforcement, the long dimension of the diamonds should always be placed in the direction of the shortest span. The ends of the sheets should be lapped the length of one diamond and the sides the width of one diamond.

131. A form of expanded metal that is used for reinforcing thin slabs of concrete, such as are used for roofs and very light floors, is shown in Fig. 49. This consists of what is called herring-bone lath, bent at the ribs, thus making a sheet that is quite stiff. This product is known as *Trussit*.

132. There are many other forms of expanded metal and metal lath on the market; many of these can be used in concrete work without forms, the metal being stiffened by ribs so that it will support the weight of a light concrete slab. Such materials are known as *self-centering*, because no centers, or forms, are required. In this form of reinforcement a sufficient

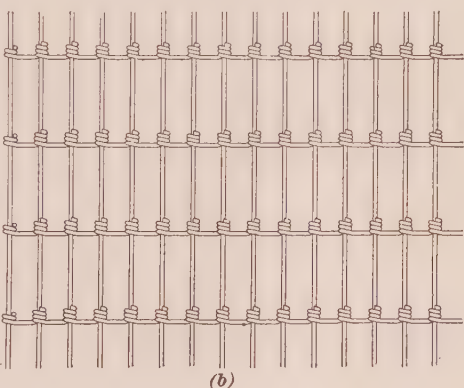
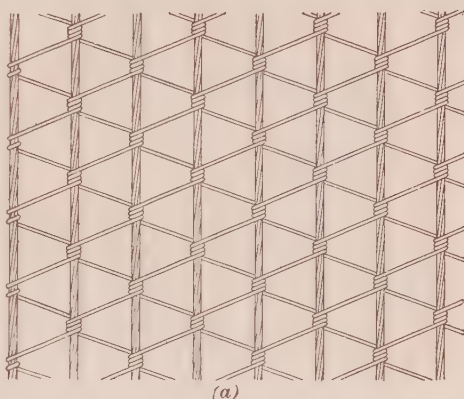


FIG. 51

amount of the concrete passes through the meshes to secure the necessary adhesion between the steel and the concrete. By this bonding of the materials, the steel provides the necessary tensile

strength to resist the stresses due to the loads in the structure.

One form of self-centering reinforcement is shown in Fig. 50. It has standing ribs *a*, and between them are expanded-metal panels *b*. This lath is shown supported by steel beams *c*. In (*b*) is shown the form of the clip with which the sheets are fastened to the beams to prevent displacement during the concreting.

WIRE FABRICS

133. For reinforcement of slabs, what are called *wire fabrics* are frequently used. These are made by weaving or welding together wires or rods into meshes having rectangular or triangular shapes.



FIG. 52

A woven-wire fabric having a triangular mesh is shown in Fig. 51 (*a*). The reinforcing parts of the fabric are the heavy members, which consist of several small wires twisted together in the form of cables.

A fabric of similar design is also made by using heavy wires or round rods instead of cables for the main reinforcing parts. These heavy strands or rods must be placed in the direction of the span, and the lighter wires serve as secondary reinforcement.

In Fig. 51 (*b*) is shown a fabric formed of wires that have been woven together into rectangular-shaped meshes.

In Fig. 52 is shown a rectangular mesh formed by welding the wires together. By this means of fastening, a solid and substantial union between the wires is obtained. Meshes of this form are made in different sizes, and fabrics are formed of different sizes of wires to meet the requirements of the loads that are to be carried.

Woven and welded wire fabrics are made in long lengths and are received at the building in rolls. They waste less material than sheets of expanded metal, as a slight lapping is suffi-



FIG. 53

cient to bond the reinforcement together, and fewer lappings will be required.

134. Fig. 53 illustrates the practical application of welded-wire rectangular-mesh fabric to a reinforced-concrete floor. The form work *a* extends between the beams *b*. The fabric *c*, which extends with the heavy wires spanning from beam to beam, is raised over the beams and droops between them nearly to the bottom of the slab, or nearly to the surface of the forms. This is accomplished by supporting the fabric upon rods *d*, one on each side of each beam. These rods extend parallel with the beams, and are held up by small iron chairs *e* fastened to the forms. When the concrete has been placed and has hardened, the forms are removed, leaving the chairs and rods in place within the concrete.

APPLICATION OF REINFORCEMENT

COLUMNS

135. Columns are reinforced either *vertically* or *laterally*, or both together. In the vertically reinforced columns the reinforcement is placed as in Fig. 54, where *a* is the concrete and *b* the reinforcement. The rods are placed as near as possible to the outer faces of column, with only enough concrete outside of the reinforcement to afford fire protection. The rods are held in the proper relative position by means of wire ties *c*, placed from 6 inches to 18 inches apart.

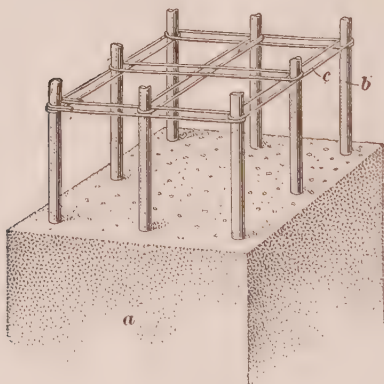


FIG. 54

In *laterally reinforced* columns, the hoop reinforcement, such as is illustrated in Fig. 55, is employed. The hoop reinforcement may be in spiral form as in (*a*) or may consist of a series of independent

bands as in (b). Both the spirals and the hoops are held at a fixed distance apart by means of separators, or spacers, *a*.

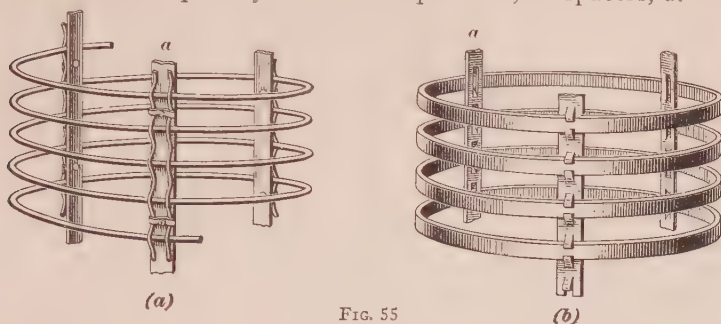


FIG. 55

136. Effect of Hoops.—The strengthening action of column hoops will be understood from Fig. 56. If a vertically reinforced-concrete column be loaded until it breaks, that is, until the concrete crushes, it will take the appearance indicated, the vertical rods *a* buckling between the ties *b*. But if the ties are closely spaced, as in a hooped column, the concrete cannot escape sideways, being held in by the hoops. The hoops furnish a jacket for the concrete and prevent it from escaping sideways, thus increasing the safety of the column. All hooping of columns should have an outside covering of concrete 2 inches thick for protection from fire and corrosion.

The hooped form of reinforcement is considered stronger than the vertical form, for the same amount of metal used. The spacers in the hooped reinforcement have a certain value as straight reinforcement and in some cases more straight reinforcement is added to the hooped reinforcement to give more strength to the column.

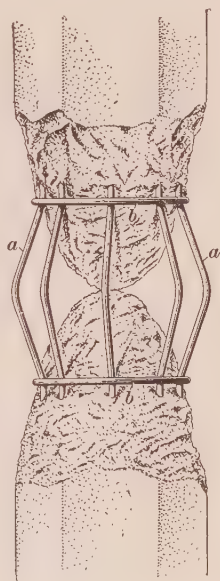


FIG. 56

As was shown in Fig. 47, this hoop reinforcement is made in units and can be folded together when shipped and opened up into the proper shape when set in position.

BEAMS AND FLOOR SLABS

137. Since steel is used principally to resist the tension stresses in beams, and since these tension stresses are located at the bottom of the beam, the steel must be placed at the lower side of all beamlike structures. The depth of a beam is measured from the top of the concrete to the center of the steel at the bottom, and the deeper a beam is, the greater is its strength. It is therefore desirable to have the steel as close to the bottom of the beam as possible in order to have a beam of the greatest possible depth and therefore of the greatest possible strength. There is, however, a limit beyond which it is not advisable that the steel approach the bottom of the beam. This depth is determined by the following considerations:

1. *Adhesion must be developed* between concrete and steel, and this is possible only when a proper amount of concrete surrounds the steel. If no adhesion were present, the steel and concrete would not act in unison and assist one another, and the beam would fail.

2. *The steel must be protected against fire.* If the heat should penetrate the concrete far enough to soften the steel, the beam would fail.

3. *The steel must be protected against corrosion.* If moisture and air should reach the steel and cause it to rust, the steel would in time become eaten up and the beam would fail.

For these reasons, concrete must surround all the reinforcement. It is customary to cover the steel of beams with $1\frac{1}{2}$ inches, and the steel of girders with 2 inches, of concrete. Where the reinforced-concrete work is especially exposed, as when near water, and especially near salt water, these dimensions should be increased.

138. Stirrups.—While it may not be easy to understand why stirrup bars are required in beams, experience shows that even though a beam contains sufficient steel in the main tension rods already referred to, it may fail by small cracks opening up in the manner indicated in Fig. 38. These small cracks may be prevented by the addition of the reinforcement

indicated in Fig. 57, the additional reinforcement being so placed as to extend into the body of the beam, as in (a), in

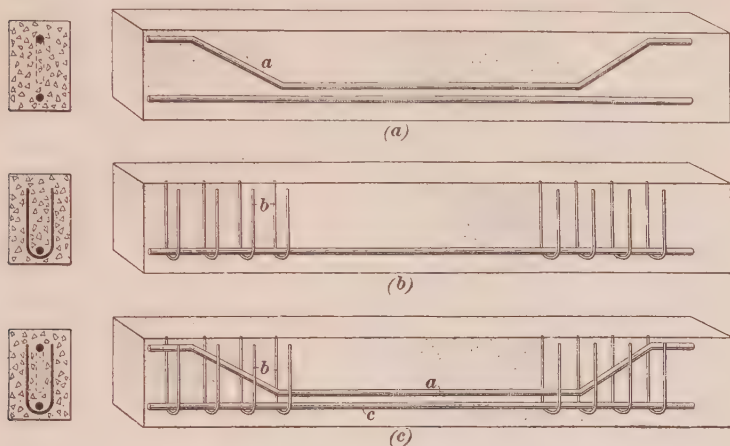


FIG. 57

the shape of bent rods *a*, or, as in (b), in the shape of light auxiliary rods *b* encircling at their bottoms the main tension rods. These auxiliary rods because of their shape are known as *stirrups* or *U bars*. In the best types of construction, both the straight rods and the stirrups are combined as in (c), where straight bars *c* and bent bars *a* extend from end to end, in conjunction with *U bars* *b* as shown.

139. Forms of Concrete Beams.—There are two kinds of reinforced-concrete beams; namely, *rectangular beams*, as shown in Fig. 58 (a), and *T beams*, as shown in (b). It has already been explained that a plain-concrete beam, such as shown in (a), may break by its tensile resistance at the bottom being overcome. By the addition of steel reinforcement to strengthen the bottom, a reinforced-concrete beam is obtained that will

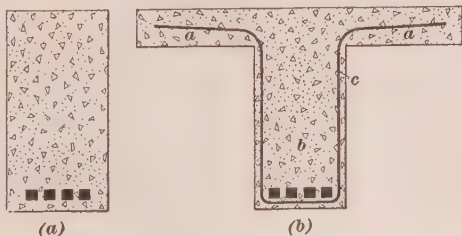


FIG. 58

break only under greater loads and by compression in the top. Since this beam has its weakest point at the top, it is desirable to strengthen the top and thereby the entire beam. This may best be done by increasing the concrete at the top. The concrete is increased, as in (*b*), by adding a flange *a* to each side of the rectangular web *b*, which is usually part of the floor slab between the beams. A beam so constructed is much stronger than the rectangular beam shown in (*a*) and is known as a **T beam**.

140. Construction of Concrete Beams.—The **T beam** is a feature of reinforced-concrete building construction which makes for great economy. A reinforced-concrete floor consists usually of beams and of floor *slabs* between the beams. It has been found entirely feasible to unite the floor slab and the beams so that each and every beam becomes a **T beam**, and the flanges of these **T beams** are obtained at no expense whatever, since the slab must be made in any event, to form the floor. The only requirement is that the flange shall be well tied to the web, as otherwise they cannot be counted upon to act in unison, that is, the slab will not act as a flange unless well tied to the web. This result is obtained by two expedients, namely, by extending the stirrups *c* so that they project well into the slab *a*, and by so placing the concrete that there is no plane of cleavage or separation between slab and web of the beam. In other words, the concrete of slab and beam is poured in one operation, so as to form one solid mass after hardening. Concrete so poured as to form one mass is called **monolithic** concrete, the meaning of the word monolithic being *one stone*.

EXAMPLES OF REINFORCED-CONCRETE CONSTRUCTION

141. Typical Exterior.—The typical reinforced-concrete building in course of construction, illustrated in perspective in Fig. 59, combines the several elements already described. This building is a warehouse of the type of construction known as skeleton construction. In this construction the exterior con-

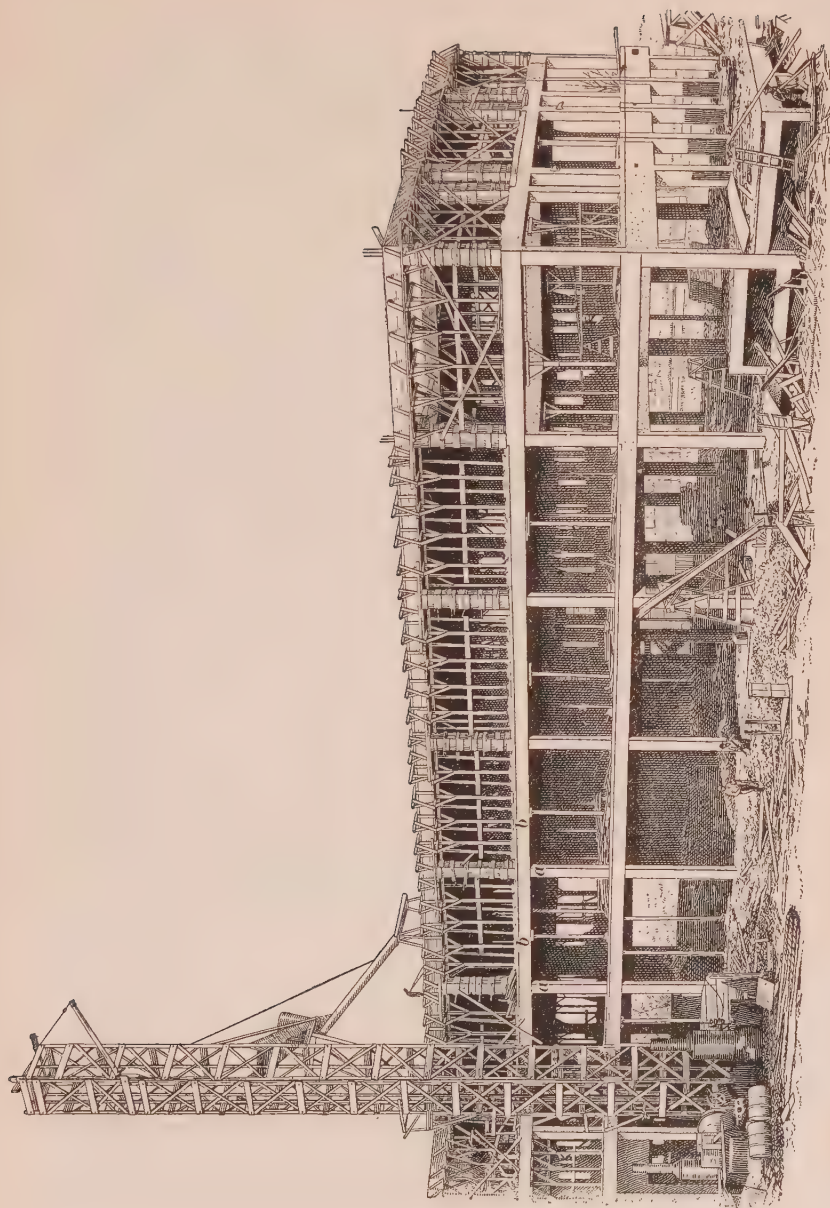


FIG. 59



FIG. 60

sists entirely of vertical piers or columns *a* and horizontal beams and girders *b*. The openings will subsequently be filled with walls up to the window-sill levels, and with sash. The beams *b* are made strong enough to support these fillings as well as a portion of the floor loads. The building when finished will present a neat and useful appearance but will not be a particularly pleasing structure from an architectural point of view.

142. In Fig. 60 is shown a completed building similar in construction to the one in Fig. 59. The same pier and girder construction will be noted, but the spaces between the piers and girders have been filled up. In most of these spaces the filling consists of a brick wall from the girder up to the window sill and a glass enclosure above. Some of the spaces, as on the side of the projecting wing, are filled entirely with brickwork. A building of this character is for utilitarian purposes entirely, space and light being the main objects sought for.

143. A typical interior construction is shown in perspective in Fig. 61 (*a*) and in sectional elevation in (*b*). This illustration shows a reinforced-concrete column which supports reinforced-concrete beams and girders. Over the beams and girders extends a floor of reinforced concrete which is monolithic with the beams and girders and is called the *slab*. The concrete is indicated partly broken away in (*a*) to show more clearly the main tension rods *a* and *b* of a beam, rod *a* being straight and rod *b* bent. These rods are encircled by stirrups *d*, and other stirrups are similarly disposed in the concrete of the main girder. The ends of the reinforcing rods of the main girder can be seen, and the ends of the reinforcement of the slab are shown projecting beyond the edge of the slab. The sectional elevation (*b*) shows more clearly the reinforcement of the main girders over the column, and especially how the bent rods of the girder are continued into the adjacent span as at *c*. The purpose of extending the rods *c* into the adjacent span is twofold: first, to tie the several parts of the building together, and second, to resist certain tension stresses which experience shows exist in the girders over the tops of the columns. A similar arrangement is used in the beams where these cross

over the tops of the girders. The general system of reinforcement in floors of the type here shown is therefore to have, in all parts, certain straight rods and certain bent rods, the straight rods being near the bottom of the member throughout their

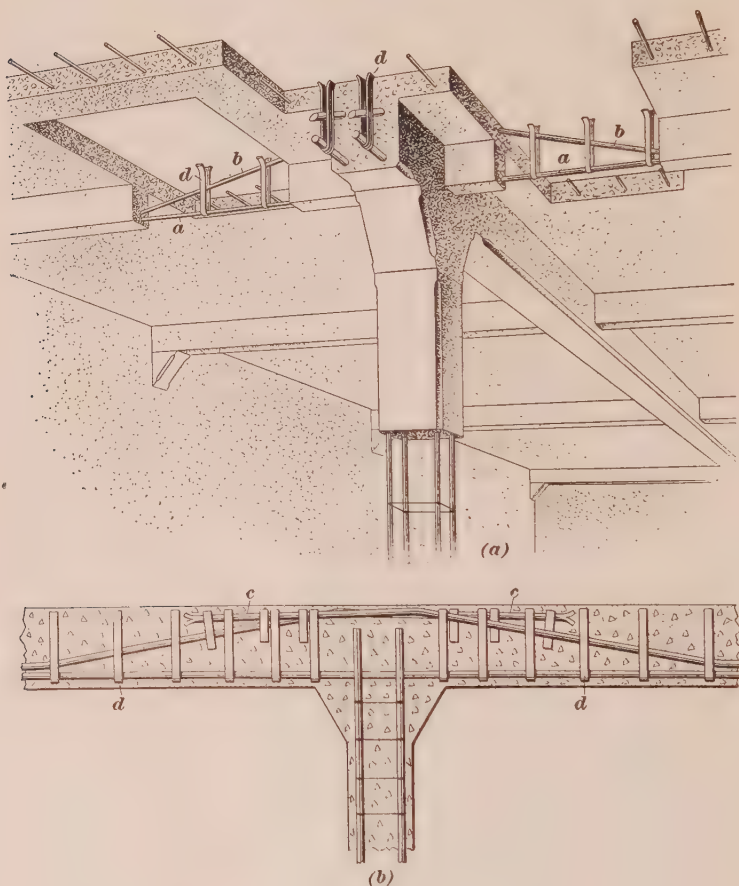


FIG. 61

length, and the bent rods being near the bottom of the member at the center of the span, and raised over the supports at the ends of the span. A building constructed on the principle shown in Fig. 61 is said to be of a *slab-and-beam construction*.

144. Tile-Concrete Floors.—While a great many buildings of the slab-and-beam type have been erected, the forms needed for their construction are complicated, and the finished ceilings are broken up by the beams and girders. The construction may be somewhat simplified by using longer spans so as to dispense with some of the beams. But, the longer the span, the thicker the slab must be, and consequently the more heavy and expensive.

In order to lighten the slabs and thereby cheapen the construction, the floor system shown in Fig. 62 is used. In this the slab consists of a number of small beams separated by hol-

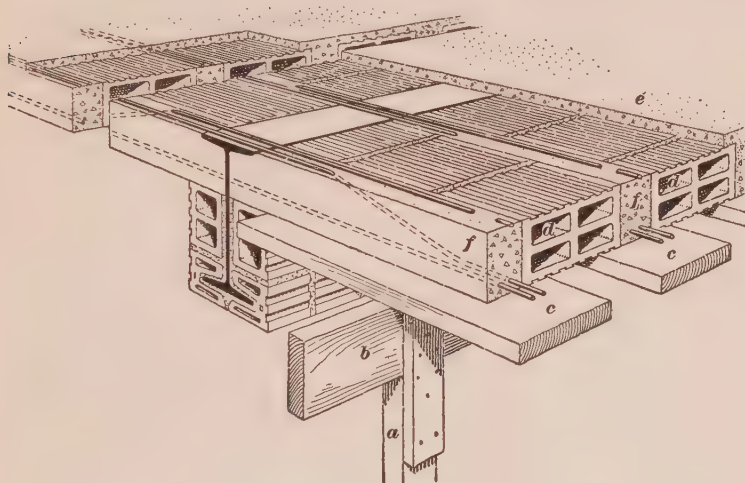


FIG. 62

low tiles, with a thin concrete slab extending over the tops of the beams and the tiles. Floors of this kind, known as *combination tile-concrete floors*, are very useful where no heavy loads are to be carried.

145. Flat-Slab Floors.—In the so-called *flat-slab floors* the beams and girders are dispensed with altogether. The floor consists merely of a flat slab which, as indicated in Fig. 63, rests directly upon the columns. This type of floor is also often called a *mushroom floor* because the columns are generally flared at the top and suggest the appearance of mush-

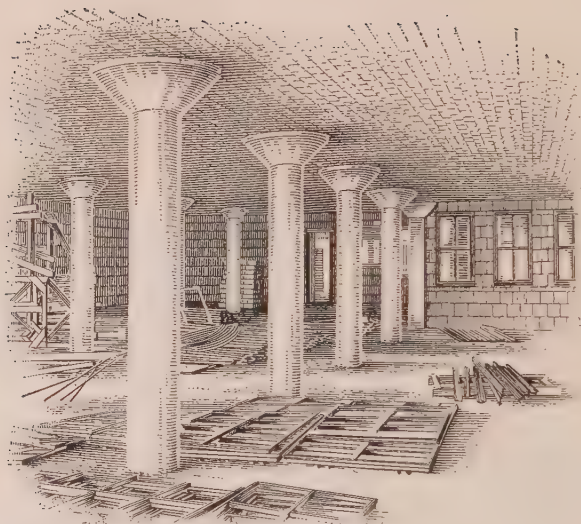


FIG. 63

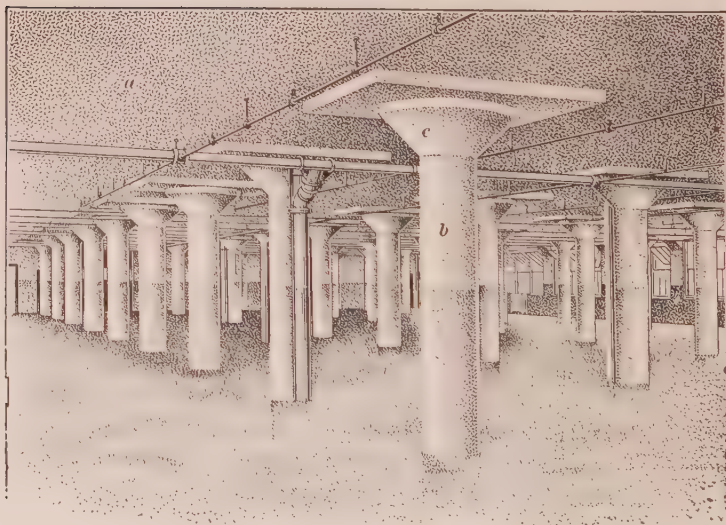


FIG. 64

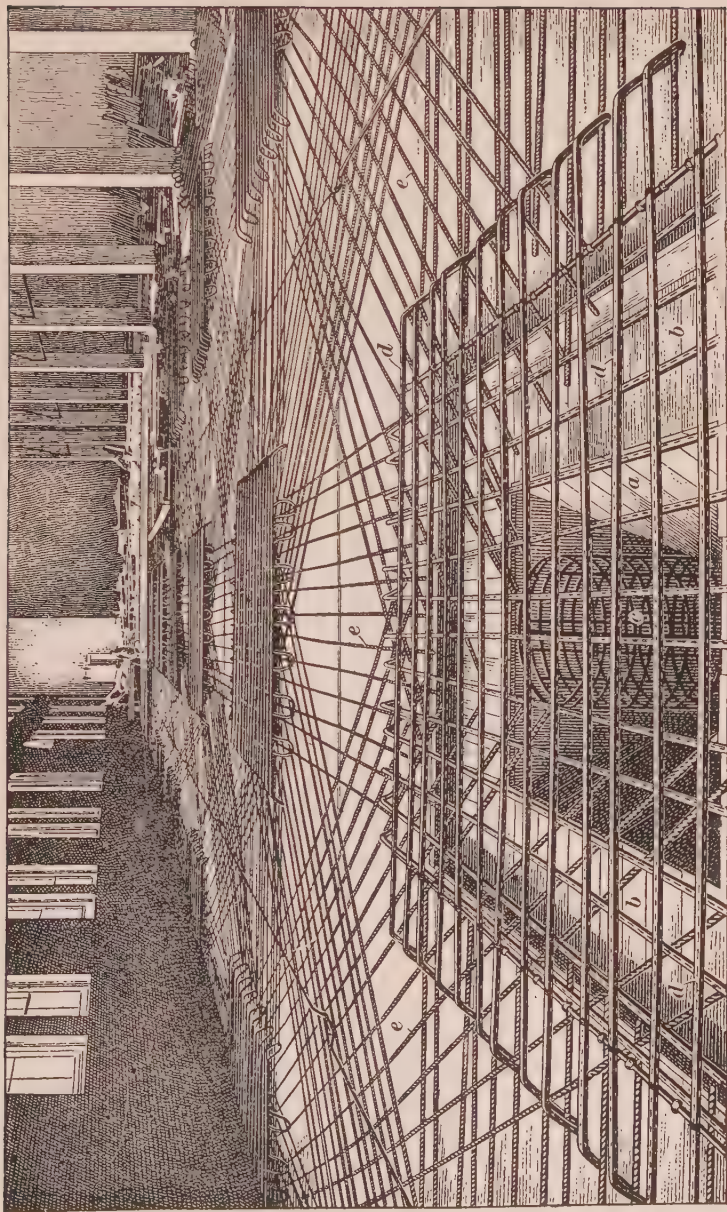


Fig. 65

rooms. Often the cap is surrounded by a thickened portion of the floor called a *drop panel*, as shown in Fig. 64. Drop panels are most common in heavy construction, such as is used in warehouses. The general arrangement of the reinforcement is shown in Fig. 65. The form for the spread cap of the column below is shown at *a* and the form for the drop panel at *b*. Hooped reinforcement for the column *c* and heavy reinforcement *d* on the top of the column are also illustrated. The slab reinforcement *e*, which consists of lighter rods, extends diagonally and also in direct belts, from column to column. As is usually the case in reinforced-concrete construction, the reinforcement is near the bottom midway between supports and raised to near the top of the slab over the supports, so that the steel rods combine to form a so-called *mat* over each column.

FORMS FOR REINFORCED-CONCRETE STRUCTURES

146. General Features of Forms.—There are many different ways in which forms for reinforced-concrete structures may be built. The method used is generally dictated by the peculiar requirements of each case or the preference of the contractor.

Forms for reinforced-concrete structures often are of the same kind as those used for structures of plain concrete; as an example, the forms illustrated in Figs. 25 to 28 could be used equally well for construction of reinforced concrete.

147. Forms are expensive items in the construction of a reinforced-concrete building and it is therefore important that they be so designed and assembled that they can be easily removed and used many times without alteration. To facilitate this repeated use, the architect or engineer should design all floors so that the beams and girders are of the same size and location on as many floors as possible. An example of such design is shown in Fig. 59, where the same forms are being used on the third story that were used to cast the similar parts of the lower stories.

It is true that beams and girders must be made stronger where heavier loads are to be carried and consequently it is not always feasible to adhere to one layout for all of the floors, but in many cases the forms may remain the same size, and the strength of the beam or girder be increased or decreased by an adjustment in the amount of the steel reinforcement that is used.

148. Forms for Columns and Piers. — Concrete columns are usually cast either in a round, octagonal, or rectangular shape. The round or octagonal column is generally used where the floors are of the flat-slab construction, and hooped reinforcement is used in them.

Rectangular piers or columns are frequently used to support floors of the beam-and-slab type, and are generally used to support the outside wall construction, as the projecting corners are less objectionable along the wall than on the independent columns in the interior parts of the building.

149. Forms for Round Columns.—The forms for round columns are usually composed of light steel plates that have been previously bent to form the curves required. These

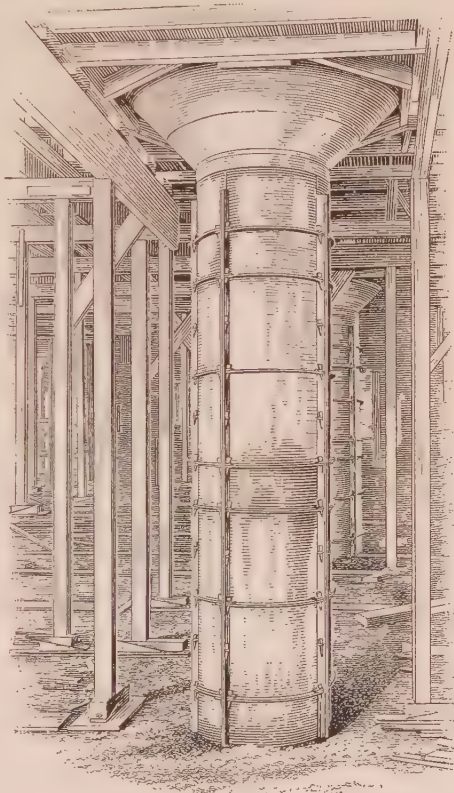


FIG. 66

plates are held together by means of bands and vertical bars as shown in Fig. 66. The bands and bars are fastened together by means of steel wedges.

Round columns that support a flat-slab floor construction are usually formed with a circular cap as shown in the illustration. The form for this cap is also made of sheet metal, the top portion having a flange that is fastened to the wooden form of the floor construction and the lower portion having a collar that fits over the column form.

Forms of this type are usually patented and are rented from the manufacturer for the period of time required to complete the job.

By the use of metal forms as described, a concrete column is cast which requires very little if any refinishing, as the surface is smooth and free from defects such as are common when wooden forms are used.

150. Forms for Square Columns.—A wooden form for a square column, or pier, which carries a beam-and-slab floor construction is shown in Fig. 67. The sides of this form are composed of boards *a*, which are held together by means of battens *b*. The upper ends of these sides have rectangular openings into which the beam forms fit. By means of this construction the beam forms connect with the column forms so that when the concrete is poured a solid concrete framework is formed.

The sides of the column forms are nailed together at the corners but this is not sufficient to hold the form intact when the concrete is poured, consequently a system of strong braces is used for this purpose. The number of these braces and the frequency with which they are used is determined by the height and size of the column. Braces for columns having considerable height and a large area should be of heavy construction and located closely together, so that they may resist the pressure due to the wet concrete in the forms.

151. The form of brace shown in Fig. 67 is of the simplest type. It consists of four timbers *c* and *c'*, *d* and *d'*. Blocks *e*, *c'*

are secured to the under side of the timbers c and c' , respectively, and blocks f and f' are secured to the top of the timbers d and d' . These timbers are assembled around the column form as shown and nailed to the form sufficiently to hold them in place until the wedges are set and driven into place. These

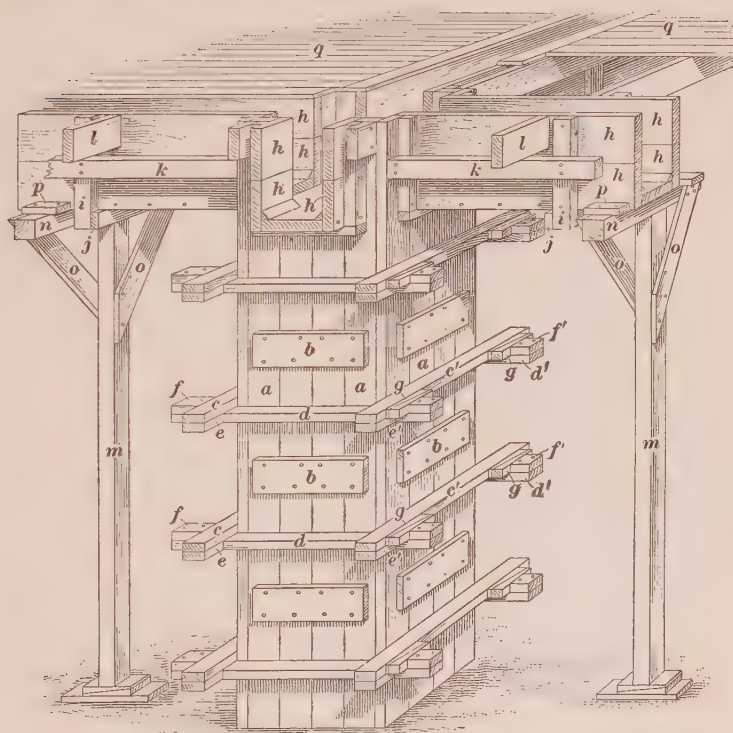


FIG. 67

wedges are used to draw the timbers into close contact with the column form.

There are many devices that are used for holding the column forms together. Some consist of metal bands, others of timbers with clamps attached, and some have bolts and wedges as shown in Fig. 19. They are all designed to be adjustable, so that after they are located in the position desired they can be tightened up and thus brace all parts of the column form.

152. In Fig. 68 is shown a device consisting of iron yokes *a*, which are attached to timbers. These devices are placed alternately on the sides of the column and thus brace all sides. In (b) the yokes are used to brace two sides of the column, and vertical timbers, as at *b*, are secured to the horizontal timbers shown and wedges *a* are driven into place until the braces are made rigid.

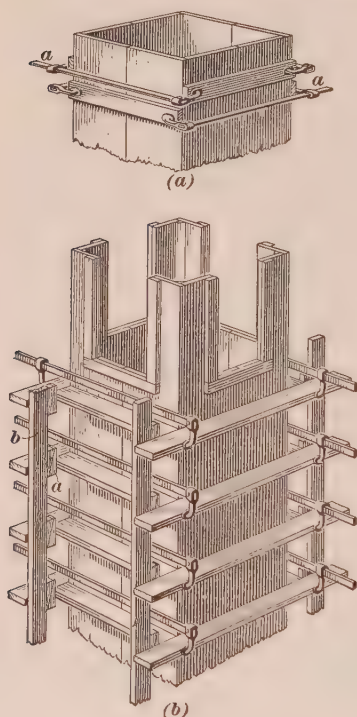


FIG. 68

153. Forms for Flat-Slab Floors.—To mold a flat-slab floor, a horizontal platform or floor at a proper height is required. Such a platform is usually made of planks, as shown in Fig. 69 at *a*, though metal plates are often used to advantage. The platform *a* is supported upon *stringers b*, which are planks set on edge and spaced usually from 4 to 6 feet apart, depending upon the weight to be carried and the size of the planks obtainable. The stringers are supported upon uprights *c* called *props* or *shores*. These are usually 4"×6" timbers placed from 4 to 6 feet apart in rows. The stringers are nailed to the up- rights and also are supported

by blocks *d* nailed to the sides of the uprights. Since the uprights are cut to about the right length, the platform will be approximately at the right height; however, to obtain a fine adjustment and a truly level surface, the uprights are stood upon wedges as shown. These wedges consist of two wedge-shaped pieces of hardwood, and by driving them farther in the platform is raised, and vice versa. The wedges also make it easy to remove the forms, since, by knocking the wedges out,

the forms are released from the concrete and can be taken apart.

A view taken underneath the forms and showing the stringers and shores in place is shown in Fig. 66 in conjunction with the column form previously described.

154. Forms for Beam-and-Slab Floors.—The forms for a beam-and-slab floor construction consist essentially of a platform of planks or boards, which is supported by stringers and posts as described in the preceding article. In addition, it

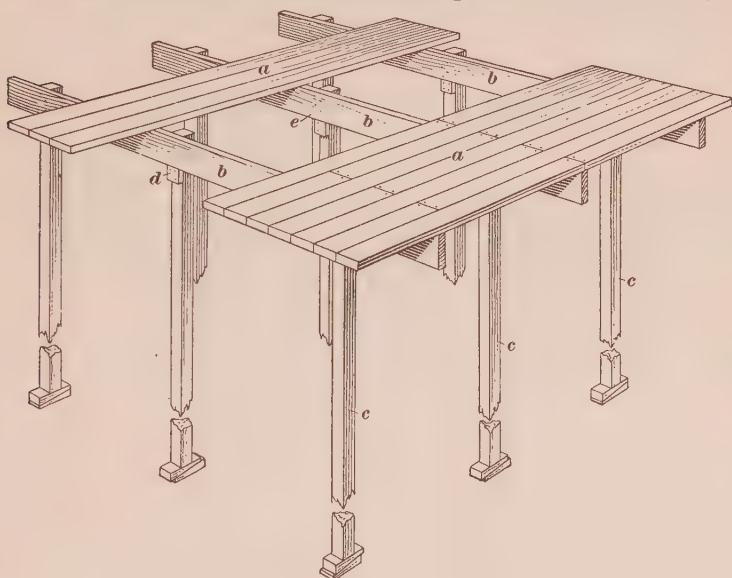


FIG. 69

is necessary to provide forms for the beams and girders. In Fig. 67 is shown one method of constructing wooden forms for this type of floor.

The trough-shaped forms for the beams and girders are built up of planks or thick boards as shown at *h* and are fastened together by means of vertical and horizontal battens *i* and *j*, respectively. To the battens *i* are secured the horizontal timbers *k* on which rest the stringers *l* which support the forms for the slabs.

In this construction the entire weight of the floor is carried by the forms of the beams, which therefore must be made very strong. The ends of the beam forms are set into openings which have been previously made in the column forms, and are thus supported at the ends. When the beams are spaced at such distances between supports that they are likely to sag under the load of the wet concrete, intermediate supports in the form of posts must be used. The posts *m* are made of either 4"×4" or 4"×6" timbers with crosspieces *n* at the top and braces *o*, which are secured to the crosspieces and posts to make a rigid support. Blocks *p* are placed on each side of the

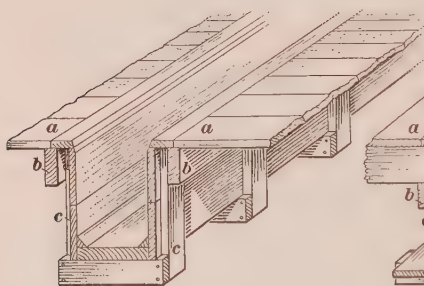


FIG. 70

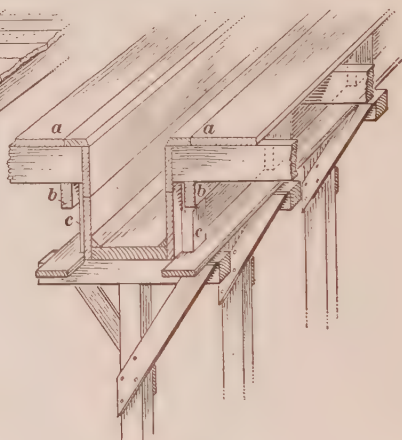


FIG. 71

beam forms and secured to the cross timbers to prevent the form from spreading when the concrete is poured. Wedges are usually placed under the posts as shown, to support the beams and to permit of adjustment.

155. Forms for concrete slabs and beams require to remain in place for a longer time than forms for columns, because the bending stresses are greater in those parts, and more time is required for hardening. To permit the removal of the forms for the columns for use in succeeding stories, the forms are so designed that those which enclose the columns may be removed without disturbing the forms of the beams and slabs. Methods

of constructing the beam and floor-slab forms are shown in Figs. 70 and 71.

156. In Fig. 70 is shown a section through the form for a beam that runs at right angles to the direction of the planks that are used for forms for the slab. In Fig. 71 is a similar section through a form for a beam that runs parallel with the planks of the slab form. In both of these figures the top of the beam form has pieces of boarding that are beveled on their inner edges, and their outer edges terminate over the centers of the stringers *b*. By this means a joint is formed in

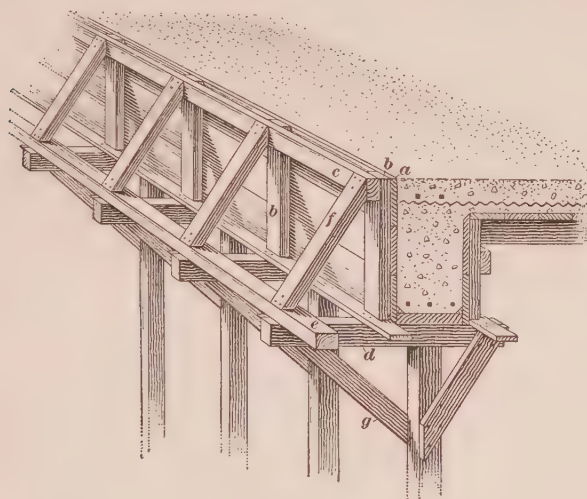


FIG. 72

the flooring around all beams so that when the floor forms are removed the separation between the floor forms and the beam forms will occur at these joints.

157. In Fig. 72 is shown a design of form, brace, and support that is generally used for an outside wall beam or girder of concrete. This form is extended on the outside of the beam to the height of the top of the floor slab, as shown at *a*. The vertical batten *b* is also extended to the same height. A horizontal 2"×4" continuous timber *c* is secured to these battens. The post support under the girder form is similar to those

previously described. The cross-bar *d*, however, is extended and a horizontal 3"×4" timber *e* is secured to these cross-bars, and between the timbers *c* and *e* braces *f* are placed every 2 or 3 feet apart to prevent the top of the form from moving when the form is filled with the concrete. The brace *g* supports the extended part of the cross-bar *d* and prevents it from sagging under the pressure on *e*.

An illustration of the use of wooden forms for columns and beams like those shown in Figs. 67 to 72 is given in Fig. 59. It will be seen that each of the column forms has six or seven battens enclosing it and each of the girders has four upright post supports, with the cross-braces at the top. These posts are stiffened by means of a horizontal timber which is placed midway in the height of the posts and securely nailed to them.

158. Treatment of Wooden Forms.—Wooden forms, both for plain and reinforced-concrete construction, are assembled as previously described. After they are set in place and lined up, they are given a coat of soap, crude oil, petroleum, or a similar substance, to prevent the concrete from sticking to the wood. Bolts which tie the forms together are also oiled. Wooden forms should not be put in place too long before filling with the concrete, because the wind and sun dry the wood and cause the boards to warp. When the forms are removed from the concrete they should be carefully cleaned, repaired if needed, oiled, and set up again. If they are not required immediately, they should be stored in a safe place for future use since they represent a very large investment.

159. Inspection of Forms.—While the concrete is being poured into the forms, it is customary to have a competent carpenter examine these forms and their supports, from time to time, in order to detect any weakness or deflection before it becomes too great to rectify. Any holes and defective joints in the forms should be plugged immediately when discovered.

160. Removal of Forms.—The order of procedure in the removal of the forms from a concrete construction consisting of columns, beams, and floor slabs is to remove the column forms first, then the beam and floor-slab forms.

161. To remove the floor forms, such as shown in Fig. 67 at *q*, the floor stringers that run parallel with the beams, as shown at *b* in Figs. 70 and 71, must be pried loose from the battens *c*, whereupon the flooring usually drops away from the concrete and the entire floor form is thus removed. If the flooring still adheres to the concrete it is easily pried loose by means of a bar. The removal of the floor forms leaves the beam enclosure and its supports as shown in Fig. 73. This beam form is usually removed at the same time as the floor-slab form.

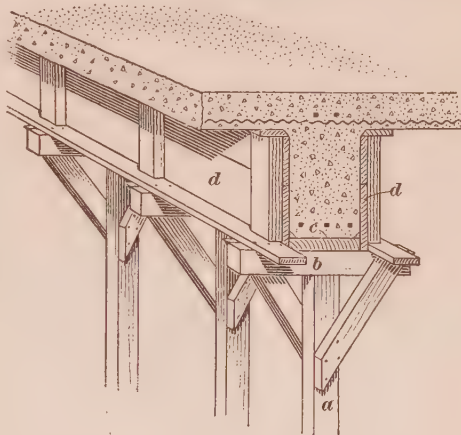


FIG. 73

162. It may be desirable to retain some of the support under the girders and beams for a time, as they are often required to carry a certain amount of load and may not have hardened sufficiently to carry the load without deflecting. The necessary support may be secured by retaining the posts *a*, Fig. 73, the cross-bar *b*, and the bottom part *c* of the form of the girder. The side pieces *d* may be removed, so that the air may reach the concrete and facilitate its hardening.

163. When the Forms May Be Removed.—There is no definite rule for the length of time which must elapse after concreting before the forms can be removed. The time depends upon the weather, the kind of cement and aggregate, the span of construction, and the thickness of the slab or mass of concrete. Only a competent and experienced person can judge when the proper time has arrived. Under favorable conditions the time may vary from one week for columns to three weeks or a month for girders and floor slabs. Some cities have

building codes containing a schedule indicating the minimum lengths of time that forms must remain in place after the concrete has been poured. This is based on the concrete having been placed when the temperature was above 32° F. If concrete is placed when the temperature is below 32° F., a special permit must be secured in some cities before the forms may be removed.

CONCRETE-BLOCK CONSTRUCTION

SHAPES OF BLOCKS

164. Definition.—A concrete block is a building unit formed of concrete molded into a convenient form. The common

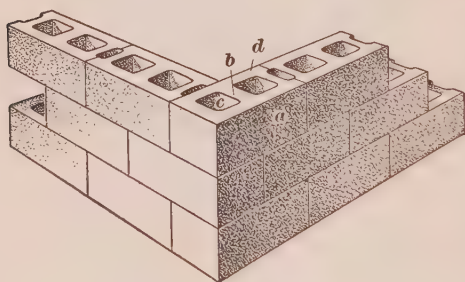


FIG. 74

shape of a concrete block is such that its exposed surface is a rectangle. The block may extend through the wall, or it may not. In every case, provision is made for an air space in the wall, and the means by

which this is accomplished vary widely and are covered by

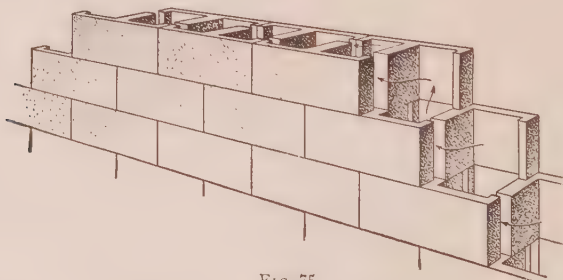


FIG. 75

many patents. The purpose of this air space is to prevent heat, cold, and dampness from penetrating the wall.

165. One-Piece Blocks.—Blocks that extend through a wall are termed *one-piece* blocks. The outer part is called the *face section*; the inner part, the *back section*; and the partitions

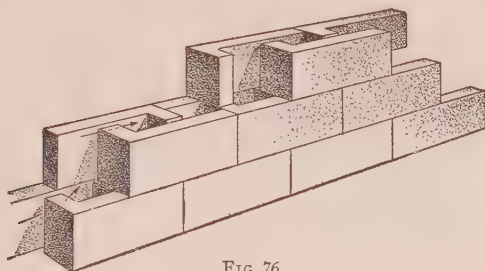


FIG. 76

that unite the face section to the back, the *webs*, or *withes*. All such blocks are termed *hollow blocks*.

Fig. 74 shows the general form of a one-piece hollow block. The face section of this block is shown at *a*; the web, at *b*; the hollow spaces, at *c*; and the back section at *d*. The spaces in one block connect with those in the block above and the one below, forming a continuous air space from the top to the

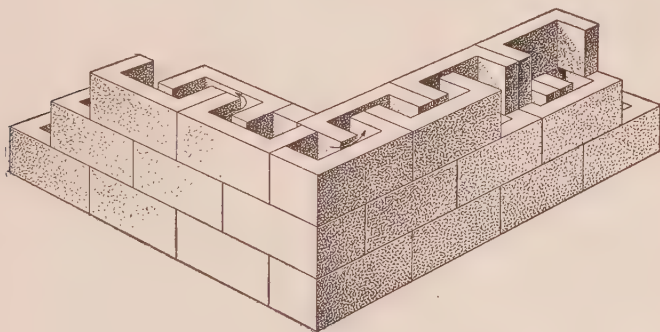


FIG. 77

bottom of the wall. Different types of one-piece blocks differ, however, in this arrangement.

In hollow blocks, the number of webs on each block may vary from two to four or more; three is the common number, as it affords two or, as in Fig. 74, three, hollow spaces.

166. Two-Piece Blocks.—Blocks in which the face section and back section constitute two separate parts are known

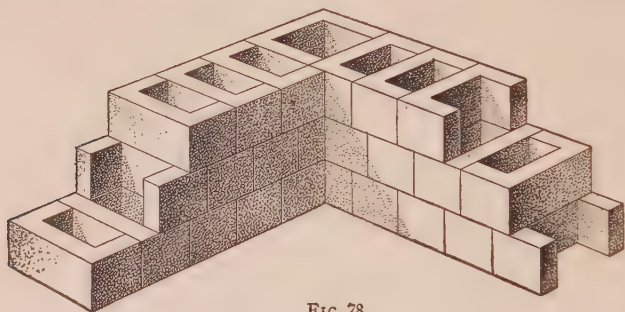


FIG. 78

as **two-piece blocks**. These blocks are of various forms and are often patented. The more common forms are designated as **T** shaped, shown in Fig. 75; **L** shaped, in Fig. 76, and **U** shaped, in Fig. 77, because their general outlines conform to the shape of these letters.

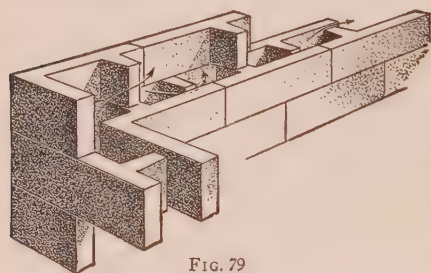


FIG. 79

These blocks are placed so as to provide as large air spaces as possible between the outer and inner surfaces of the wall.

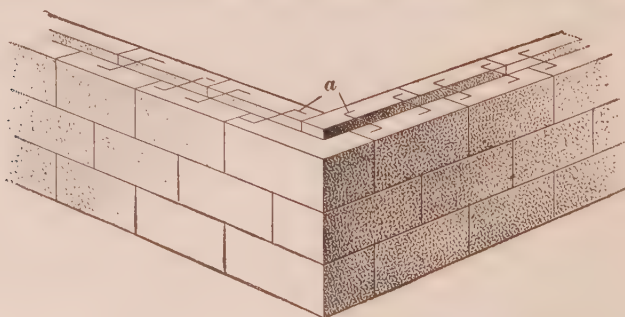


FIG. 80

Fig. 78 shows a wall that is made up of **U**-shaped blocks laid crosswise, instead of lengthwise, as in Fig. 77.

The type of block used in the wall shown in Fig. 79 is an unsymmetrical form of the T-shaped block.

In laying two-piece walls, the blocks on the back of the wall break joints with those on the front, so that the only joints

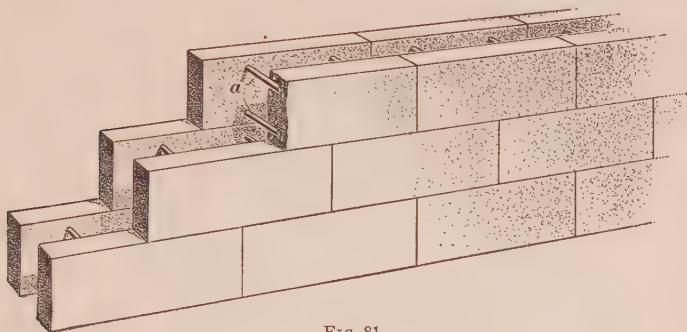


FIG. 81

extending through the wall are the horizontal ones between the courses.

In Fig. 80 is shown a form of block in which two slabs, one forming the face and the other the back, are joined by metal ties *a* laid in mortar on top of each course. This gives the general effect of a one-piece block, the only difference being a

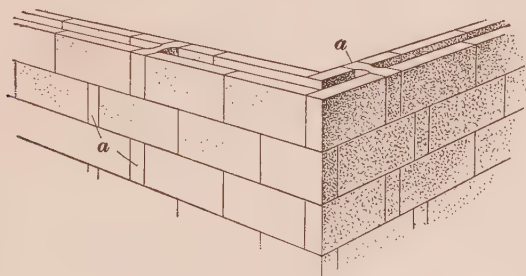


FIG. 82

continuous air space throughout the wall, as the transverse webs are omitted and the metal ties perform their function.

Another type of two-piece block that produces a continuous air space is shown in Fig. 81. Each pair of blocks is permanently united by means of four rods *a*, that are embedded during the casting process.

Fig. 82 illustrates a type of two-piece wall in which the face and the back portions of the blocks are laid entirely separate, the two halves of the wall being connected by headers *a*.

The wall shown in Fig. 83 is built up of blocks that have triangular projections. As indicated by the arrows, there is a

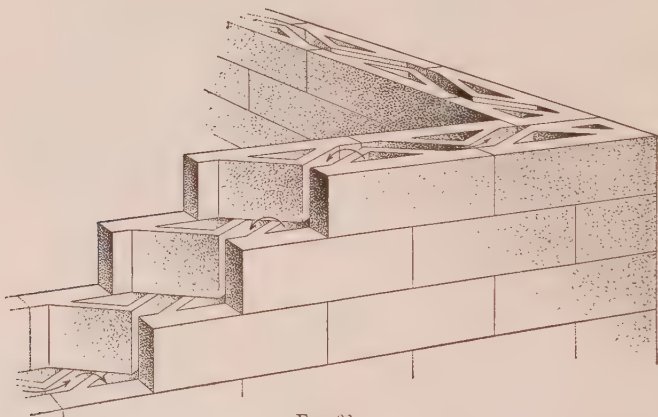


FIG. 83

very free passage of air through the blocks, in both horizontal and vertical directions.

MANUFACTURE OF BLOCKS

167. Processes.—There are three different processes that may be used in the manufacture of concrete blocks; namely, pouring, pressing, and tamping the concrete into forms or molds. The pouring process makes use of a comparatively wet mixture and produces an excellent product. A medium-wet or sometimes quite dry mixture is used in the pressing process, the concrete being pressed into the forms by means of hydraulic or other power. The tamping process employs a dry mixture, the material being shoveled into the forms and tamped into place.

Blocks may be cast in a very simple form of mold, but are generally formed by means of machines. Numerous types of molding machines, using all three of the processes mentioned, have been placed on the market.

168. Cement-Block Machines. — Cement-block machines are made in many designs, each manufacturer claiming that his machine possesses certain superior features. In all these machines there is a framework that supports the mold, in which the block is cast, at a convenient height so that it can be filled and handled easily. The sides and ends of the mold are usually hinged together or connected in such a manner that the mold can be easily opened and closed.

Most of the machines on the market are what are known as the *face-down* type, in which a comparatively dry mixture of

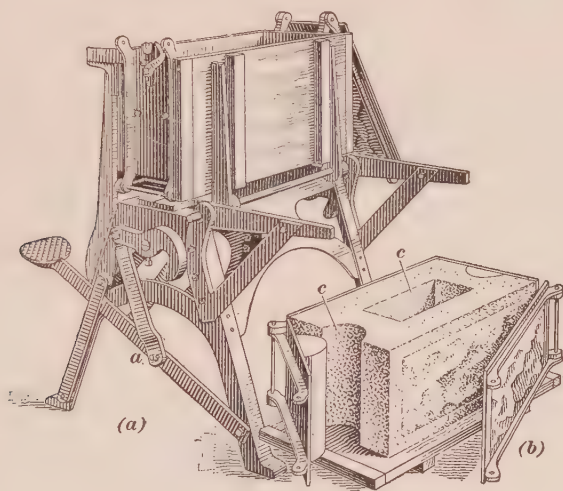


FIG. 84

concrete is used. In these machines the face of the block is at the bottom of the mold during the period of filling. The wood or metal cores, which are placed in the mold to form the hollow spaces *c*, Fig. 84, occupy a horizontal position while the mold is being filled. In the machine shown in the figure, after the block is molded the mold is turned by means of the lever *a*, and the core can be removed vertically. The semicircular cores are attached to the mold and are removed with the mold. In this block there are special faces on the top and bottom of the block, as it is designed to show on opposite sides of the wall.

169. Other types of machines are those known as *side-face* machines, because the face plate is on one side of the mold; and *press-block* machines, which press the concrete into the form of blocks. Many of these machines have interchangeable face plates whereby the exposed face of the block can be finished in different designs such as plain face, rock face, imitation ashlar, tooled face, and other finishes that are used in cut stone work.

SURFACE FINISHES FOR BLOCKS

170. Concrete blocks may have surface finishes similar to those described for walls of poured or cast concrete. Some

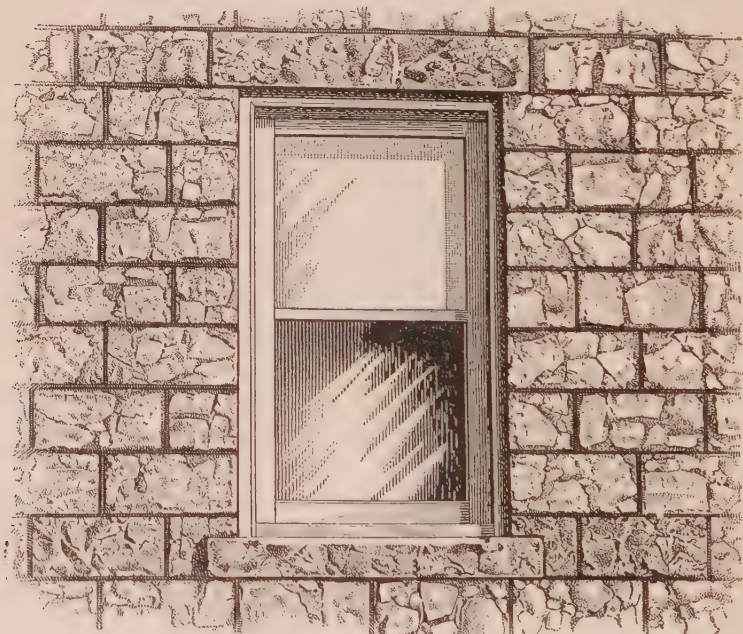


FIG. 85

additional finishes of an attractive character are also possible because of the manner in which the block is made.

For blocks that are to be veneered with a special mixture of aggregate, the mixture is placed in the form first and the rough

concrete is deposited on top of it. The treatment of the block after it is taken from the form may be by any of the processes described for walls.

171. There is a form of veneer for the blocks which presents a face consisting largely of actual stone that is very pleasing. To secure this form of surface, a layer of sand about $\frac{1}{2}$ inch in thickness is first spread over the bottom of the form. Upon this sand are placed thin pieces, or chips, of granite having irregular shapes and sizes, these pieces being usually split by hand from larger pieces. They should be laid in the form as close together as possible without overlapping. A rich mortar consisting of one part cement and one part sand, mixed very wet, is then poured into the forms, sufficient mortar being used to cover the stones. Immediately after pouring this mortar, the forms are filled with ordinary concrete, and the blocks are left in the forms until the following day. They are then removed, stored, and allowed to dry slowly, as is customary with ordinary concrete blocks, and without further treatment are ready to be placed in the wall. A wall formed of this style of concrete blocks is shown in Fig. 85. The joints between the blocks may be pointed with a colored mortar and finished in the form of a raised bead.

SIZE AND WEIGHT OF BLOCKS

172. Size.—The size of a concrete block from the face section to the back is variable, because the width is regulated by the required thickness of wall. This dimension can be changed by lengthening or shortening the connecting webs. It is customary, however, in thicker walls to make some variation in the thickness of the face section and the back of the blocks. In this way a larger bearing surface is afforded and increased resistance to unequal expansion is obtained in case of excessive heating of one side of the wall. On the other hand, the decrease in thickness of face and the back sections in narrow walls carrying light weights not only serves to increase the insulation afforded by the interior air space, but also effects

some saving of material. The thickness of walls as customarily specified are as given in Table III.

173. The length and height of the blocks are determined by three factors: (1) Facility in handling and laying; (2) preservation of a multiple system; and (3) appearance in the completed wall.

The general tendency has been to make as large blocks as possible in order to reduce the manufacturing cost per square foot of wall. The expense of handling large blocks is, how-

TABLE III
THICKNESS OF WALLS FOR BUILDINGS OF VARIOUS HEIGHTS
(Thickness of Partitions, 4 to 6 Inches)

Height of Building	Thickness of Wall, Inches				
	Base- ment	First Story	Second Story	Third Story	Fourth Story
One story	12-15	8-10			
Two stories	15-17	10-12	8-10		
Three stories	17-20	12-15	10-12	8-10	
Four stories	20-22	15-17	12-15	10-12	8-10

ever, objectionable. Consequently, blocks 16 inches in length are the most common size, being light enough in weight to be handled by one man.

The heights of the courses are generally 4 inches, 8 inches, or 12 inches, which simplifies construction.

174. Weight.—The weight of a concrete block is determined by its composition, its size, and its percentage of air space.

Weight is important because of the cost of handling and because of the load on the lower courses and the foundation. In general, the aim should be to keep the weight low enough in one-piece blocks so that one man can handle a block on the wall. When these weights are exceeded, it usually means paying an extra man to assist in handling the blocks, and he is necessarily idle part of his time.

